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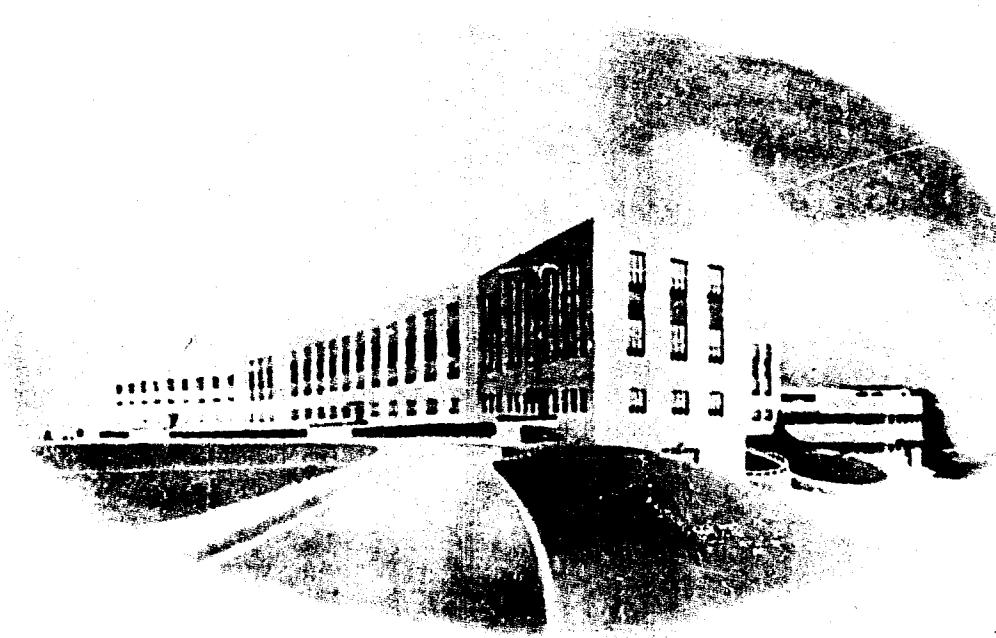
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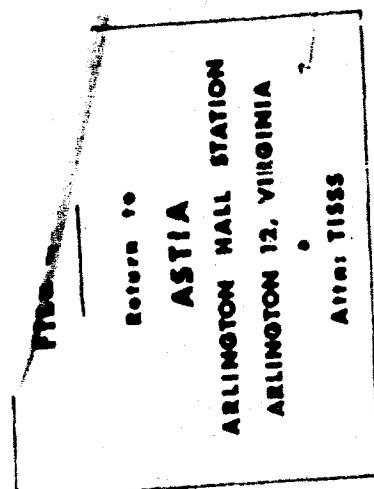
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NAVAL MEDICAL RESEARCH INSTITUTE



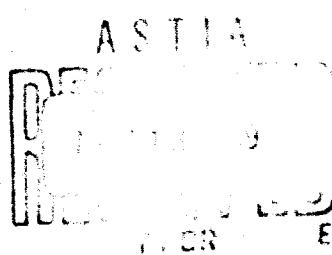
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SEA WATER RADIOPHYSICAL MONITORING METHODS

RESEARCH REPORT
NM 62 03 00 01 01

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SEA WATER RADIOLOGICAL MONITORING METHODS

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Vol. 19

pp. 119-172

RESEARCH REPORT
NM 62 04 00.04.01

**NAVAL MEDICAL RESEARCH INSTITUTE
BETHESDA, MARYLAND**

13 March 1959

ABSTRACT

The dispersal in time and sea of radioactive contamination produced by a deep underwater atomic blast was studied. Instrumentation methods obtained radiation intensity versus depth information for several surface locations, and continuously monitored a sea-water intake line aboard ship. Surface contamination measurements were also made. This work was performed in conjunction with marine biological surveys by the University of Washington and oceanographic studies by the Naval Hydrographic Office.

The original concept for this study was proposed by Dr. W.R. Boss, Zoology Department, University of Syracuse, Syracuse, New York.

This project was supported jointly by the Division of Biology and Medicine, Atomic Energy Commission, and the Naval Medical Research Institute.

Classified figures removed from this report are available from Lt. J. W. Duckworth, with proper clearance certification.

Submitted by author 17 December 1958.

Issued by the Naval Medical Research Institute.

INTRODUCTION

Background

Three studies were performed aboard the U.S.S. Reliance in support of the WAHOO underwater event of Operation Nickelback. Pre-shot environmental surveys were accomplished by the Naval Hydrographic Office under Project 1-18. Pre- and post-shot marine biological studies were conducted by the University of Washington representatives of Program 40. This report will contain the results of the third study, that is, a feasibility study of sea-water radiological monitoring methods made by the Naval Medical Research Institute personnel in association with Program 40 are reported.

Objectives

The dispersal of radioactive contamination produced by a deep underwater shot is not well understood. The distribution in time and sea of radioactive marine biological specimens has been studied several times. Oceanographic factors, such as prevailing currents, water temperatures, salinity, etc., have been investigated for the purpose of correlating dispersal phenomena. The present study provided several instrumental approaches to supplement these efforts. The original objective of studying the feasibility of several instrument designs for monitoring (1) the water immediately external to, and (2) the internal water supply of a ship, was maintained. Surface contamination measurements were made, also.

PROCEDURE

Instrumentation

Limited preparation time dictated the adaptation of existing equipment where possible. A quick estimate was made of sensitivity and functional requirements for the determination of radiation intensity at various depths in sea water. Certain Drill Hole Logging equipment, developed by the Instruments Branch of the Health and Safety Laboratory, was reconditioned and made available for this purpose.

A special ionization chamber was designed and fabricated to detect contamination of the internal sea-water supply of the ship. Standard Navy portable radiation survey instruments were provided in several types and ranges, and a simple gamma-ray spectrometer was included.

Drill hole logging equipment. - This equipment is pictured in figure 1. A complete copy of the operating instructions prepared by the designers appears as appendix B. The two units used were mounted rigidly in a sheltered thwartship passageway on the boat deck about midships. Booms and blocks were rigged to allow free cable play when lowering the probe into the water. Depth casts were made only from the port side of the ship. This side was always positioned into the wind when lying to and drifting dead in the water. Average drift rates always exceeded measured ocean current speeds.

A bathythermograph, which alone weighs about 40 pounds, was attached to the radiation probe for additional ballast. This technique made possible a measure of maximum depth attained for any cast. This information, when combined with cable angle measurements and known cable footage in use, gave a good approximation of true depth at any time. The radiation probe was allowed to descend at a maximum rate consistent with recorder and read-out response times. This assured minimum wire angles and penetration to maximum depths. The slow recovery rates available made depth estimates more uncertain during that portion of a cast. The reel used was found to contain approximately 800 feet of cable.

The scintillation detectors of this equipment were designed to measure gamma radiation intensities ranging from background (average 0.0015 mr/hr. at sea) up to about 10mr/hr. (figure 2). Location of separate detectors at main deck level on either side of the ship might have provided a directional navigational aid toward outlining areas of surface contamination. Unfortunately, the ship was subjected to heavy fallout just prior to the WAHOO event, and the high background rendered this equipment of little value for the purpose. However, available sensitivity ranges proved optimum for depth probe studies.

Sea water intake monitor. - A continuously recording radiation detector indicated the presence of increased near-surface water contamination and gave some concept of the growth rate and amount of radioactivity within the internal water supply of the ship.

Sea water from the main intake is supplied to the ship's evaporator. Most of the supply passes through the cooling system and a small amount is used to produce fresh water. The cooling water discharge line presented a 3-inch straight section of 3-inch (inside diameter) pipe with sufficient work space about it. This line was actually quite close to the sea intake and was considered, with its high flow rate, to offer a representative continuously available sampling of sea water. A large ionization chamber was fashioned in two halves and installed completely around this line. The chamber had outer guard shells of aluminum with two concentric $\frac{1}{8}$ -inch-thick carbon daged lucite plates mounted inside on standoff Kel-F insulators. A $1\frac{1}{2}$ -inch spacing was maintained between the plastic plates and the total active volume was calculated to be about 10 liters. The two chamber halves were connected electrically in parallel and the whole assembly formed a rubber-gasketed moisture-proof unit. A tube of silica gel drying agent was attached to insure dry air for the chamber cavity which was allowed to assume local temperature and pressure.

A 300-volt charging battery was connected in series with the chamber plates and a Keithley Instruments Inc., Model 410 micromicroammeter. Output of the ammeter was applied to an Esterline-Angus 0-1 milliamperc chart recorder which displayed the chamber ionization current as a function of time.

Protect calibration experiments with this chamber are included in appendix A. The instrument is pictured in figure 3.

Standard radloc equipment. - Standard Navy Radiac equipment was placed aboard the ship, presumably for emergency use only. Two AN/PDR-27C instruments, which measure gamma radiation in the 0-500 r/hr. range, were included. One AN/PDR-43 (XN-2), 0-500 r/hr. range, and assorted quartz-fiber pocket ionization chambers were provided also. The AN/PDR-27C instruments were recently calibrated and agreed reasonably well with each other and with the ship's survey instruments.

The high contamination levels aboard ship during the operational phases precluded the use of more sensitive instrumentation. All surface contamination outlines were performed by the simple expedient of stationing a three-man team in the bow of the ship, equipped with the Navy survey instruments. All readings were recorded along with the time and other pertinent information. Readings were transmitted immediately to the bridge by a phone talker system.

The gamma-ray spectrometer. - A simple pulse height analyzer was assembled in the laboratory. A sodium iodide well crystal detector was used. A shop-built preamplifier and window analyzer, patterned from a circuit developed by Dr. P. R. Bell, et al. (1), was adapted for use with a standard Navy Radiac computer-indicator unit. This unit, known as a CP-79, is a component of the Radiac Set UDR-9. It consists of an exceptionally well stabilized and regulated high voltage supply, a linear amplifier and timing-pulse generator section, and a decimal scaling indicator. All power requirements for the analyzer and preamplifier were taken from the CP-79. Pulses from the detector were applied to the linear amplifier and the output was fed to the analyzer. Output of the analyzer could be put back into the scaling indicator of the CP-79, or applied to a separate ratemeter. A modified Nuclear Instruments Model 1615 ratemeter was used and its output was displayed on a Brown Electronik chart recorder.

The combined instrumentation was calibrated frequently with Cs-137 and Na-22 counting sources. The ratemeter ranges were extended to accommodate samples containing several microcuries of activity. This equipment is pictured in figure 4.

RESULTS

Presentation methods

A consideration of all information accumulated at similar times and positions will insure a proper perspective. Smooth plots (figures 37 to 42) on surface charts of the work area show position of the ship as a function of time. Radiac survey instrument readings at the bow station are entered on these charts and depth cast positions are indicated. Individual plots of radiation intensity versus depth have corresponding cast numbers (figures 22 to 36), these linear plots show recorded times, wire angles and surface radiation intensities. A series of plots (figures 5 to 18) show relative radiation intensity versus time as recorded by the sea water intake monitor. Relative intensity versus time information was obtained also, with the depth scintillation probe in a fixed position at the boat deck rail, when the ship was underway (figures 19 to 21).

Log of operation. - The ship was lying to at a position 7000 yards from the shot buoy on a bearing of 190° at shot time. Thirty-seven minutes later, the move toward a position upwind and south of the zero point was started. At $H + 1$ hour, or 1430, the first contact with increased radioactivity was made. The ship's position was determined at frequent intervals by the intercept of three bearings per point and a running plot was made. Smooth plot No. 0.002 (figure 37) shows the course followed until 1610, or $H + 2\frac{2}{3}$ hours, ending at a position 6500 yards directly downwind at the edge of the measured activity.

The sea intake monitor plot (figure 7) showed the first contact with contaminated water to be at 1451. This should mark an actual edge of the activity mass and depict an area of "shine" to account for elevated bow readings at earlier times. The next actual contact occurred at 1610, and a depth cast at this point substantiates the presence of activity in the first 50 feet of water. The ship had drifted partially off the active mass before recovery of the probe.

A surface drogue was released on the downwind edge of the active mass at 1600 on 16 May. This consisted of a 55-gallon empty drum with a pole and flag attached above the water surface and a nylon parachute suspended just below the surface.

After cast I was completed, the ship maneuvered south to disembark a passenger. Smooth plot 0.002A positions the next direct contact at 1904. The active mass was penetrated to the second highest recorded level by the near-surface and surface monitors.

Cast II did show subsurface activity during the probe's descent but the recovery portion produced little response.

At the end of cast II, the ship proceeded south again, drifted, and then started a spiral course during a midwater fish trawl. This was followed by an all-night drift with no further operations until morning.

Cast III, at 1000 on 17 May, was made about 10.5 miles west of shot point near the surface drogue in an area containing numerous dead fish and much debris. Little activity was recorded even to the 500-foot depth. Increased surface activity was registered by the sea intake monitor during this period.

Cast IV, at 1248 on 17 May, was made in an area about 3 miles north of the 1000 drogue position. Definite activity levels were recorded to depths of 300 feet and the sea intake monitor showed a peak during this period.

In maneuvering to cast IV position, the ship passed through an area just 4 miles from shot point with no measured activity increase. Following cast IV, the ship proceeded due east toward shot buoy and intercepted a radioactive mass at 1620 on 17 May at a point actually a mile west of the noon inactive position. A short run placed the ship on the upwind side of the mass as measured by detectors in the bow.

Cast V produced the highest probe readings obtained at a depth of some 70-100 feet with an apparent lower limit of the active mass at 170 feet. The cast payed out 765 feet of cable with no further activity contact. The probe had drifted out from under the mass before recovery was accomplished and showed no increased readings for the trip to the surface.

The ship returned immediately to a position 1 mile north of the start of cast V and cast VI was begun at 1950. The maximum readings occurred at depths similar to the situation of cast V but were of lower amplitude. During cast VI, an attempt was made to pass the probe repeatedly through the lower limit of the active mass as the ship drifted west. This technique did produce the highest readings at the middle depths at 2040. A single drift over the mass could only produce information along one vertical plane. The sea water monitor recorded increased activity at points which coincided qualitatively with depth count data.

The decision was made to perform a third drift trawl across the mass between the lines of casts V and VI. This was started at midnight after making the second midwater fish trawl over the area due west of cast V. Cast VII contained all night and passed over a point of maximum activity, by surface monitor, between 0230 and 0800 on 18 May. The probe was at the lower limit depth of the active mass at this same hour. This cast was accomplished completely on motor-driven power for the cable reel. The probe descended at a rate of 10 feet per minute and was recovered at about half this speed. At 0430 the probe was positioned with 250 feet of cable out and allowed to trawl at this depth until morning. Readout was switched from the depth versus intensity recorder. This trace is plotted in figure 19.

Cast VIII was made near the shot point at 1037 on 18 May. Little activity remained in this area.

Cast IX measured some activity at a point northwest of shot point. Some streaming of water currents close around the stoll might be suspected. Cast X was made a short time later at almost the same surface position with much lower activity levels possibly demonstrating the passing of an activity mass.

Casts XI and XII were made at some distance west of shot point and produced near background radiation levels.

DISCUSSION

Instrument reliability

The Drill Hole Logging equipment functioned properly until after the end of cast XI. A loose connection, probably in the high voltage section of the probe, produced intermittent response. Immediate repair attempts failed but a thorough check-out upon return to the laboratory placed the original probe back in operation. No water leaks developed with this probe, even at 600-foot depths. The second probe admitted salt water, probably during its first immersion, and remained inoperative after the descent portion of cast XII.

Storage batteries furnished by the ship were checked frequently under load and exchanged as required. The 1.5-volt battery in the probe was renewed at least every 8 hours.

The ion chamber monitor performed without incident. On two occasions the chart recorder paper jammed for short periods of time. This instrument combination operated continuously in a humid environment with air temperatures ranging to 120° F. The stability and reliability of the micromicroammeter under these extreme conditions was very satisfactory.

All Navy Radiac equipment functioned as rated. The gamma spectrometer produced data which have not been evaluated.

Interpretation of results

The depth probe was calibrated against a radium source. A curve obtained appears in figure 2 in units of $\mu\text{r}/\text{hr}$. versus counts per second. The Navy Radiac equipment was calibrated in $\mu\text{r}/\text{hr}$. units. Direct comparison of the two instrument types would require similar exposure situations. The bow survey meters viewed a large solid angle, but were shielded from the nearby water surfaces. When the depth probe was in a fixed position at the rail of the boat deck, about half the total solid angle was shielded by the ship but a better view of nearby waters was possible.

Such a comparison is more difficult between the immersed depth probe and the sea intake monitor. The latter instrument defined a fixed volume of water calculated to be about 3 liters. Current readings could be converted to $\mu\text{r}/\text{hr}$, if certain assumptions are made for the conversion of radioactivity to dose units.

The effective volume of contaminated water responsible for a given reading from the submerged probe must be estimated. A complete knowledge of source composition and energy spectrum would permit calculation of these factors.

Analysis of the data to provide useful information on dispersal phenomena really requires only relative treatment. Each individual type of instrument depicts radiation intensity as a function of position and time. Efficiency in mapping dispersal is therefore dependent upon the strategic sampling of position and time.

CONCLUSIONS

Qualitatively, the various types of data obtained agree well. A thorough analysis may permit some quantitative correlation but this has not been attempted seriously in this report.

The following qualitative impressions may be inferred from this study:

1. The fireball bubble did vent through the water surface to some extent.
2. The base surge phenomena distributed a large amount of activity in the upper water layers over an area of about 1-mile radius.
3. Prevailing winds carried airborne water and contamination in a westerly direction to form an initial elliptical contaminated surface area with the leading edge some $2\frac{1}{2}$ miles west of shot point at $H + 2$ hours. This contamination extended to depths of 50 feet.
4. Highly contaminated areas may be detected easily from a safe distance to avoid actual contamination of a ship's water supply.
5. Near-surface contamination dispersed rapidly. Movement of the surface drogue is cited.
6. At least a major portion of the initial bubble of contamination was trapped below the water surface. A hemispherical, active mass is envisioned extending to a 300-foot depth. This mass was outlined on three occasions. The effects of current and time seemed to elongate the mass in a westerly direction. Diffusion to some extent appeared evident.
7. A sequence of measured radiation intensity maximums for the major active mass show the effective rate of decrease to be greater than the normal radioactive decay rate for gross fission products. Surface vessels could traverse the most active areas without serious contamination 24 hours after this type of shot.

8. The more active mass was estimated to move at about 0.17 mile per hour for the first two days or 8 miles, then increase speed to about 0.20 mile per hour.

9. Near-surface contamination probably traveled at speeds comparable to the drogue or about 0.67 mile per hour.

10. At least some streaming of surface activity close in around the atoll in a northwesterly direction was suspected.

11. Preshot contamination of the ship reduced the flexibility of this study considerably.

Future studies of similar design may benefit by the following suggestions.

1. A rapid recovery system for the depth probe equipment would have allowed more discrete sampling.

2. The importance of surface position would indicate the use of very precise methods for this determination.

3. Several ships working simultaneously would be an asset. Useful radiation intensity levels become dispersed rapidly.

4. Cable lengths should be sufficient to permit bottom sampling.

5. A complete analysis of energy spectrum and source composition would be required for a full interpretation of instrument data. These factors can be assumed to change with time, making repeated analyses necessary.

6. A study of the salt-scale samples from any ship's evaporator may produce a sea-water sampling method of simple proportions. A considerable concentration factor for radioactivity occurs normally in this system.

ACKNOWLEDGMENTS

Mr. H. D. LeVine, and his staff, of the Instruments Branch, Health and Safety Laboratory, were especially generous and helpful. This efficient organization located, reconditioned, and loaned the Drill Hole Logging equipment used by the project and instructed personnel in its repair and operation.

The officers and crew of the U.S.S. Rekobeth gave support and assistance which was exceptional in quantity, quality, interest, and willingness.

The combined effort of three operational groups aboard the same ship was applied efficiently because of a prevailing spirit of sincere cooperation and mutual assistance.

The Model Shop, Metal, of the Naval Medical Research Institute, produced the working model of a sea-water intake monitor with speed and precision. Special credit is due Mr. J.L. Hollis and Mr. G.W. Pearce.

The tireless efforts of the Institute's Radiation Technology Division personnel, especially our expeditor, HMC C. R. Biles, USN, placed this project in the field on schedule.

REFERENCE

- Francis, J.E., Bell, P.R., and Harris, C.C. Medical Scintillation Spectrometry. Nucleonics, November 1955, Vol 13, No. 11, pp. 82-88; McGraw-Hill Publishing Company, Inc., New York.



Figure 1. - Drill Hole Logging equipment.

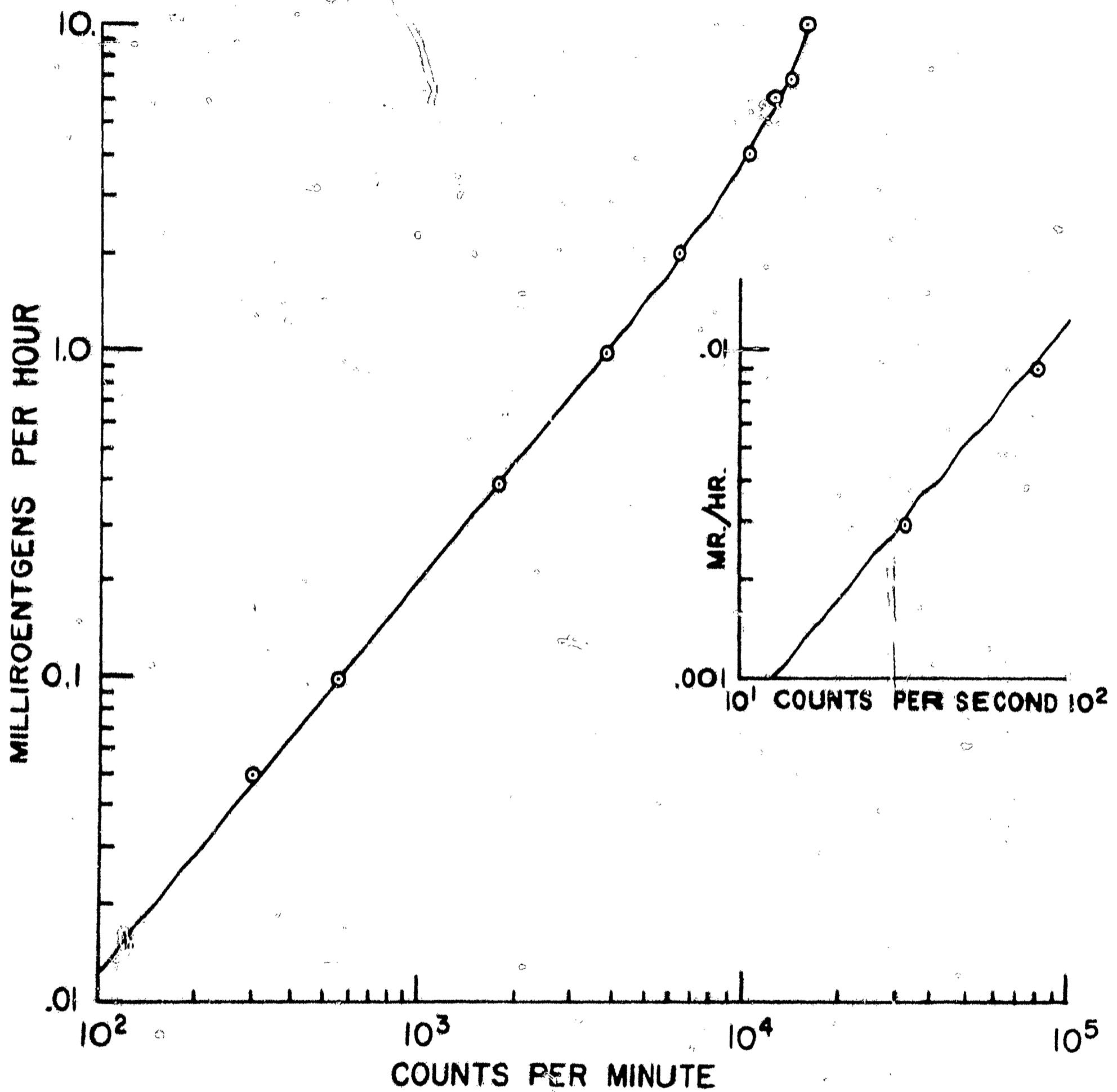


Figure 2. - Radium calibration—Drill Hole Logging probe.

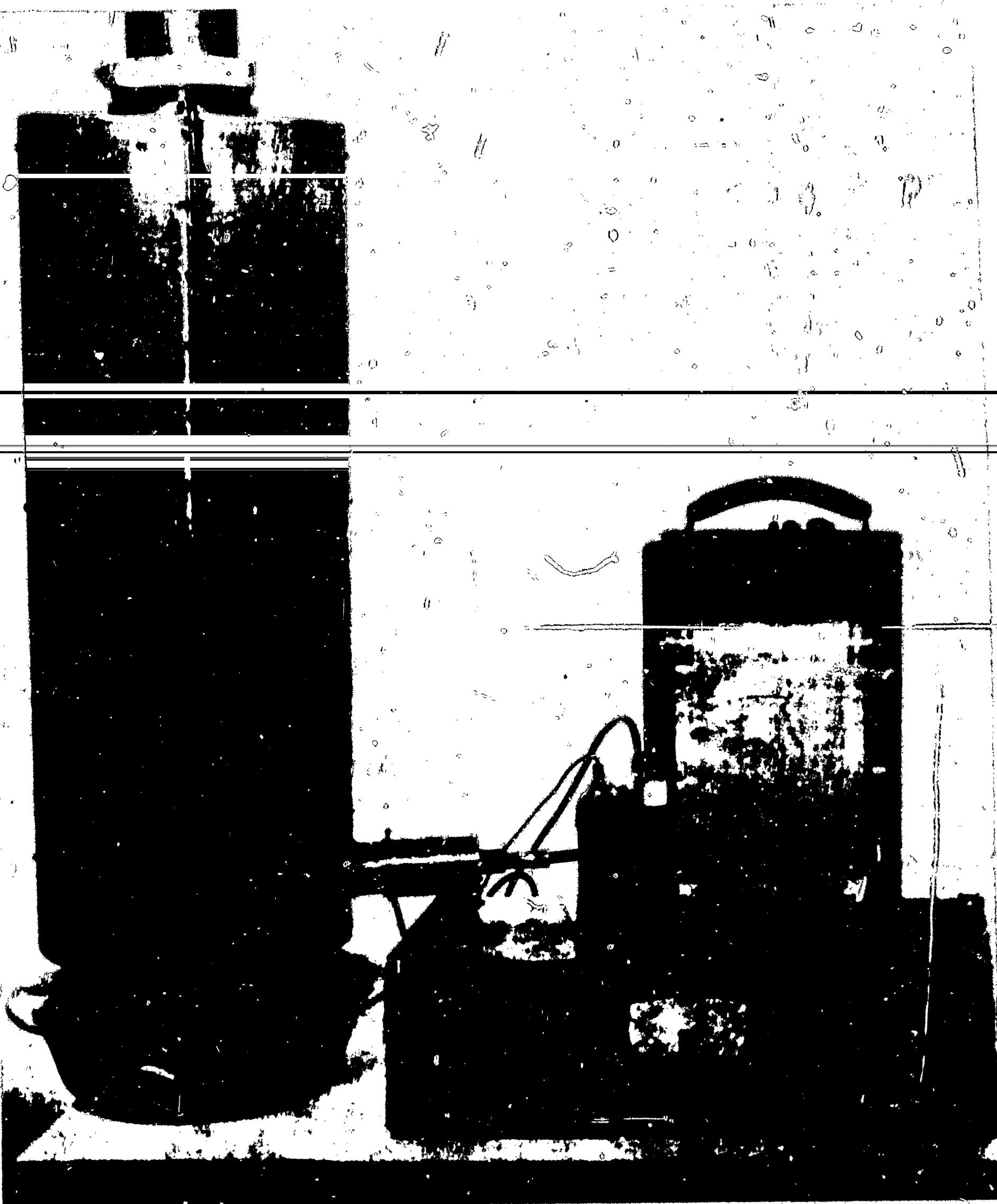


Figure 3. - Sea-water intake monitor.

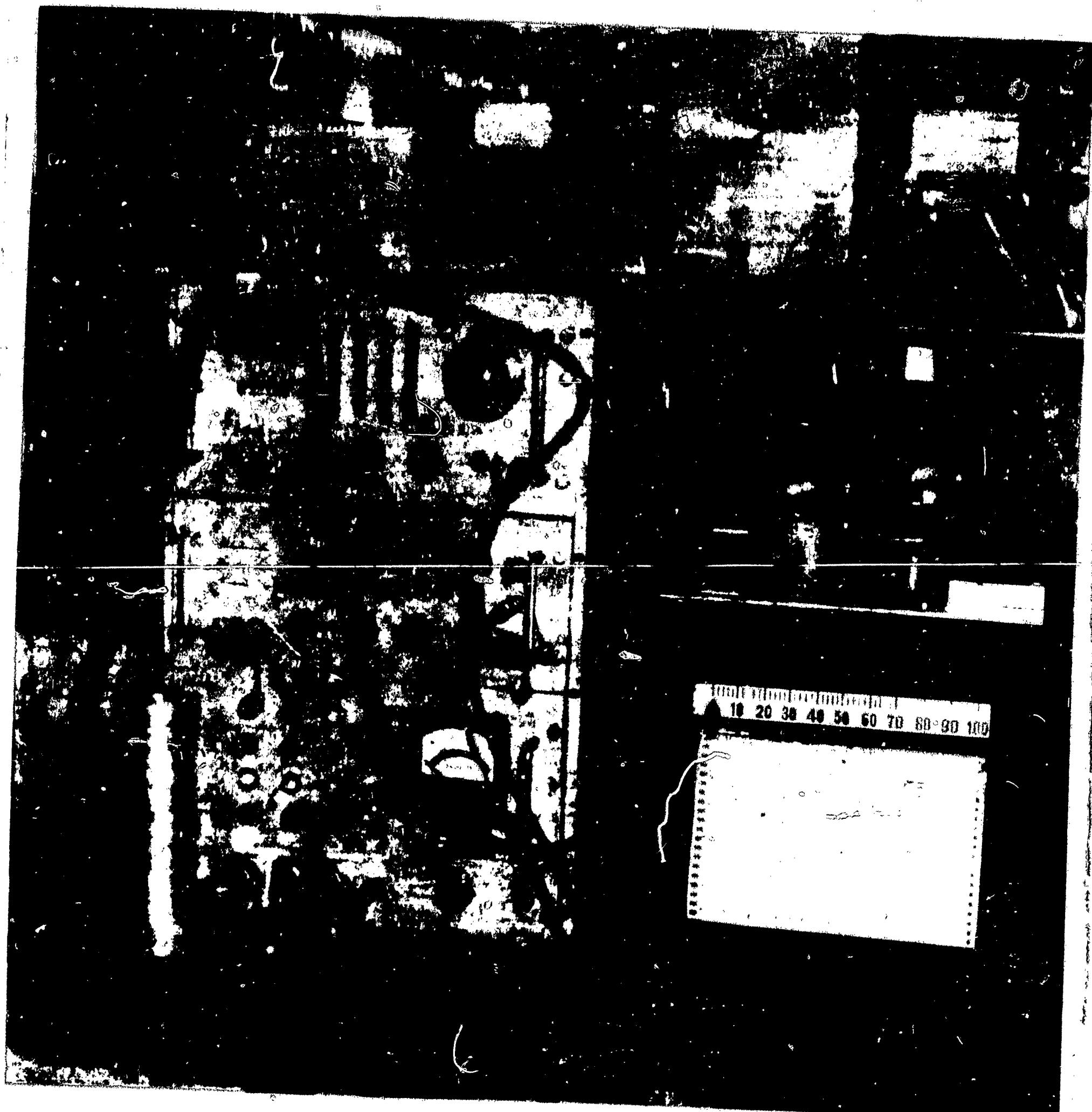


Figure 4. - The gamma-ray spectrometer.

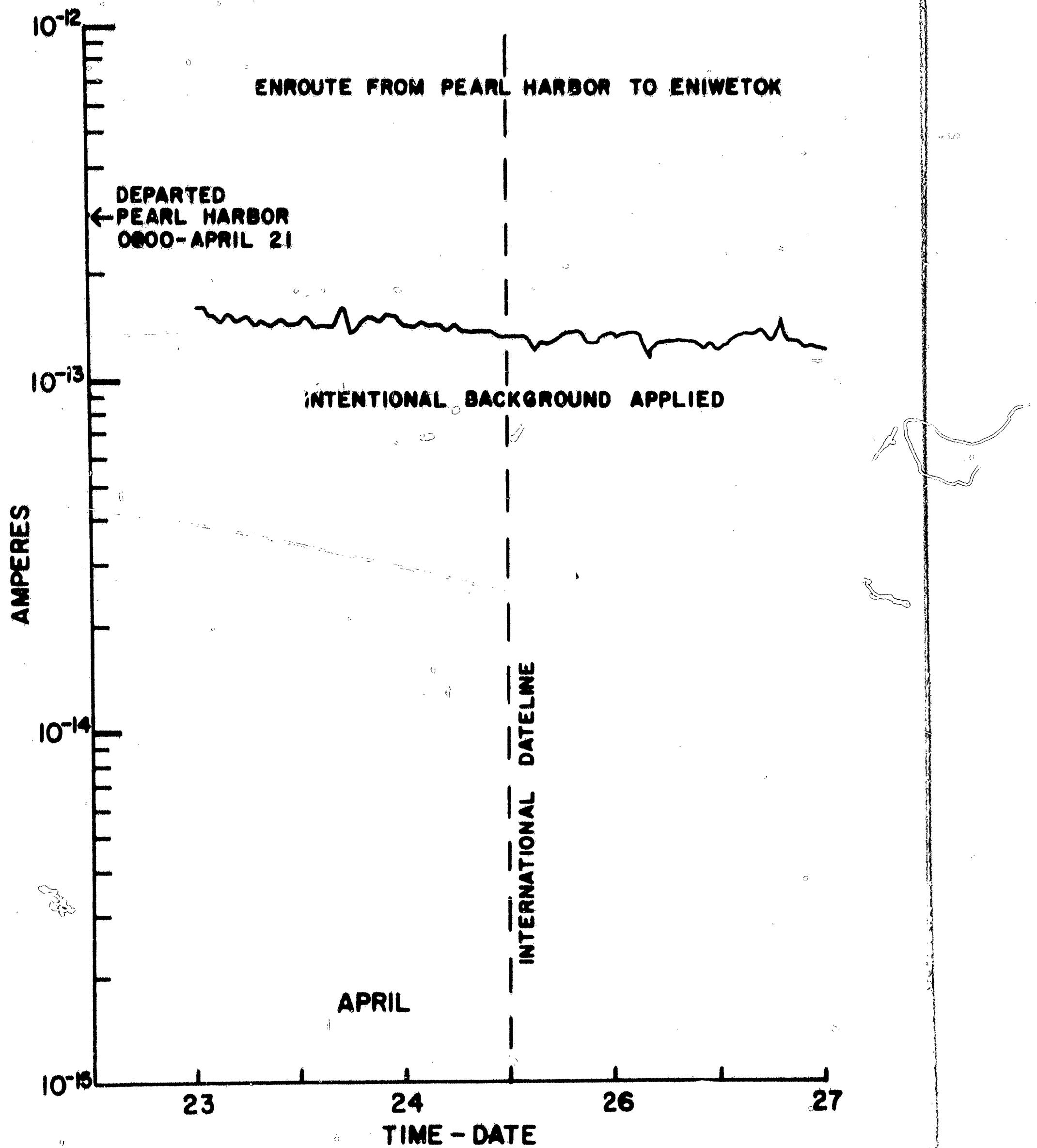


Figure 5. - Serial plot--sea-water intake monitor data. (Radiation intensity versus time.)

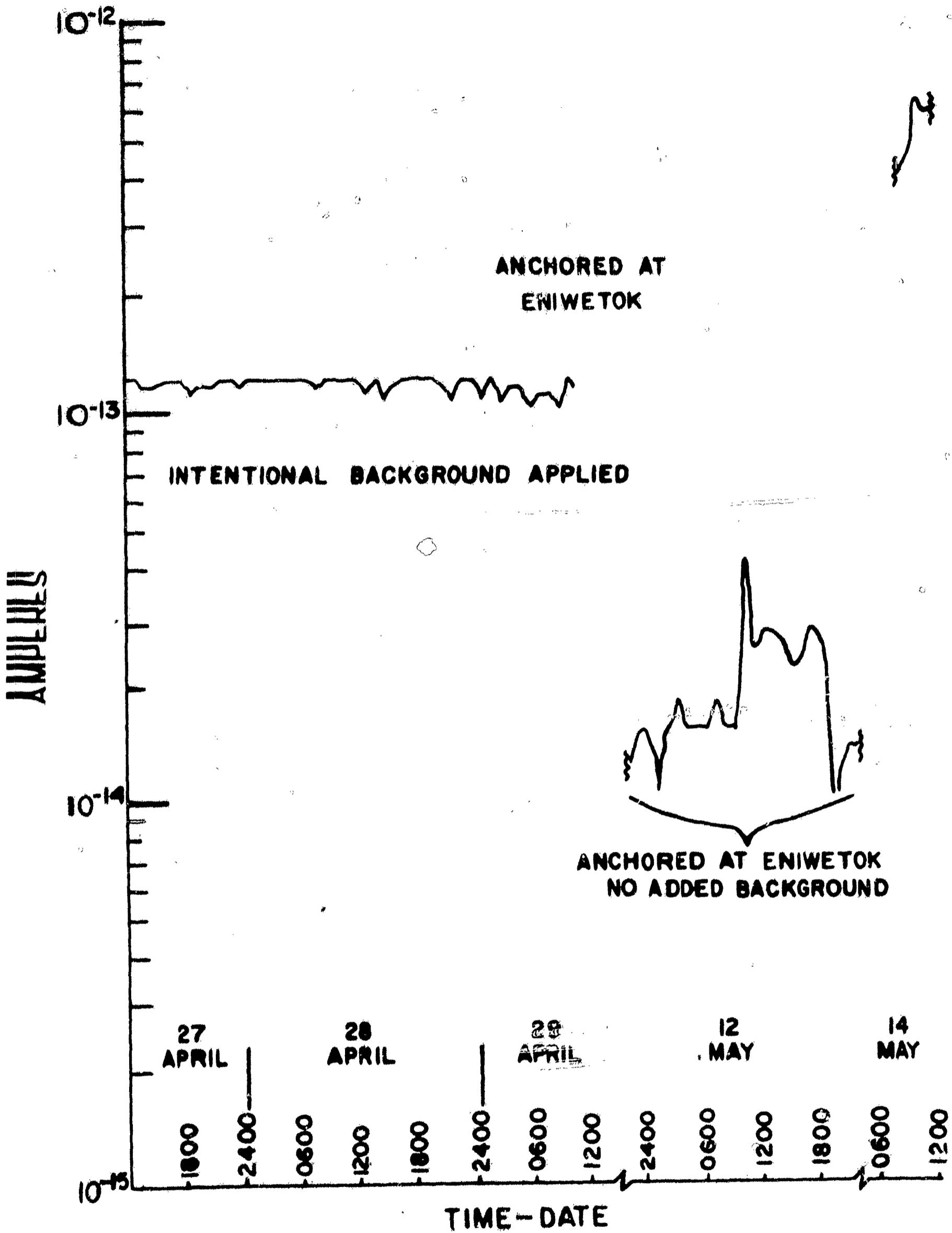


Figure 6. - Serial plot--sea-water intake monitor data. (Radiation intensity versus time.)

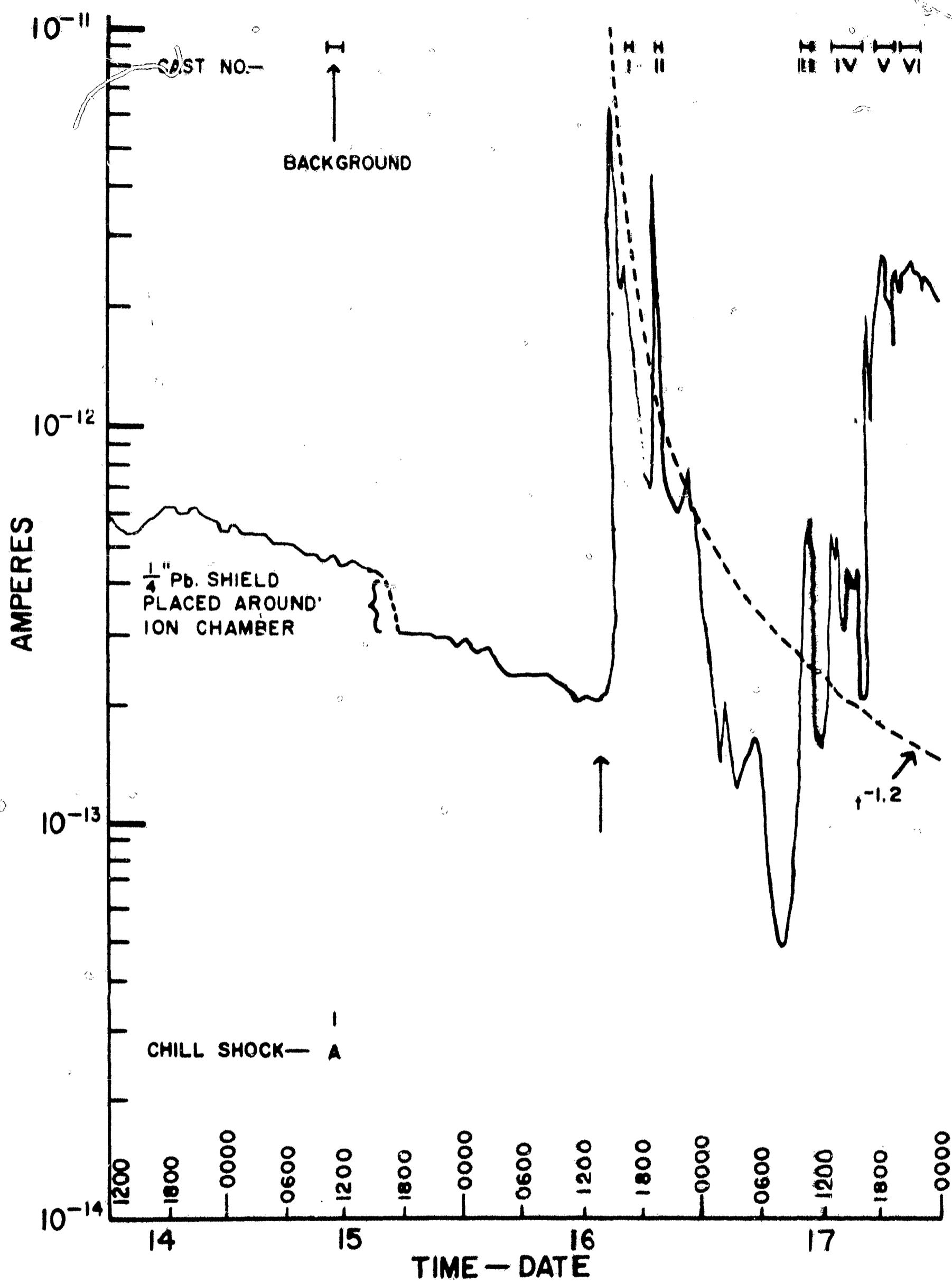


Figure 7. - Serial plot—sea-water intake monitor data. (Radiation intensity versus time.)

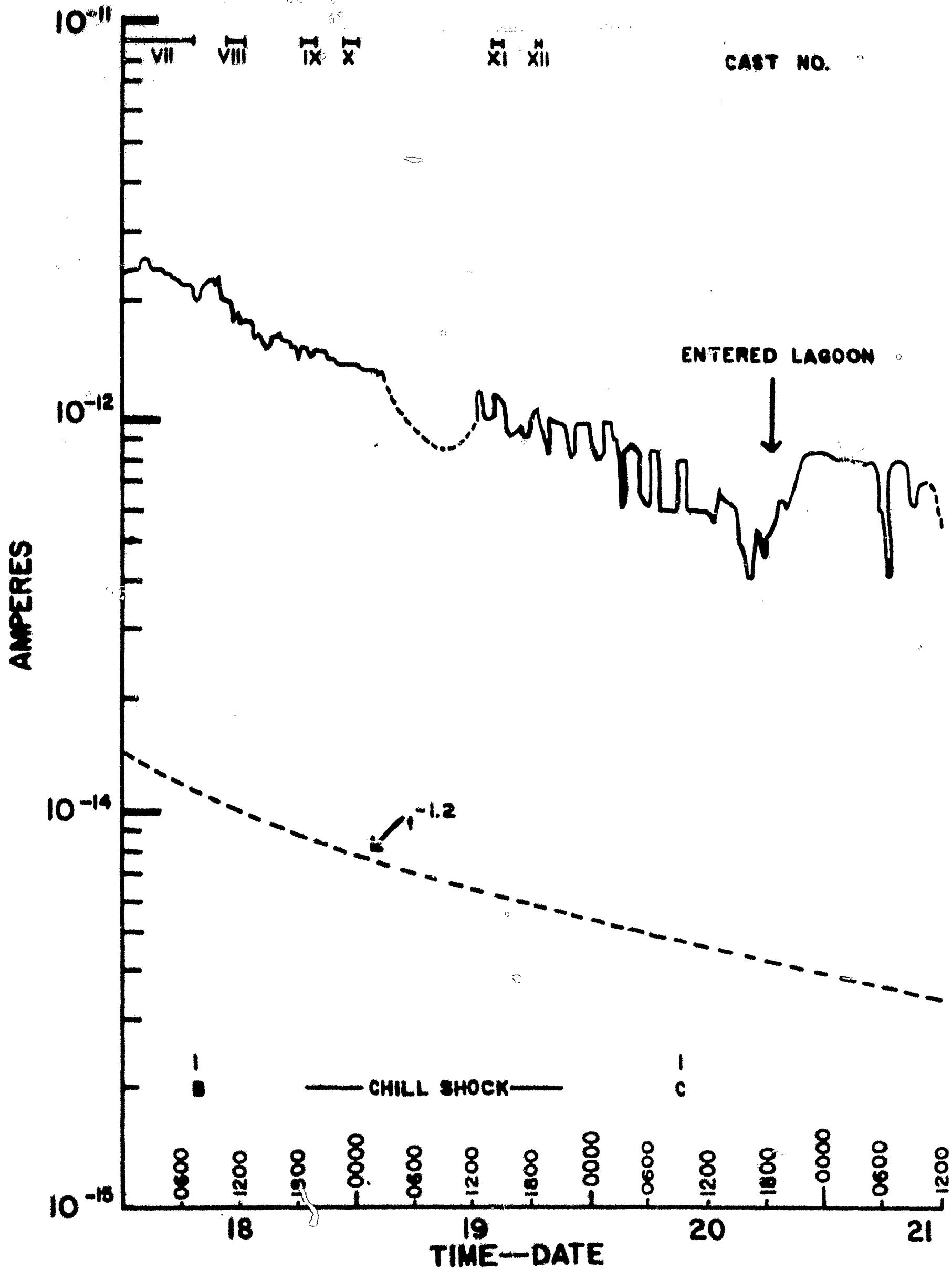


Figure 8. - Serial plot—sea-water intake monitor data. (Radiation intensity versus time.)

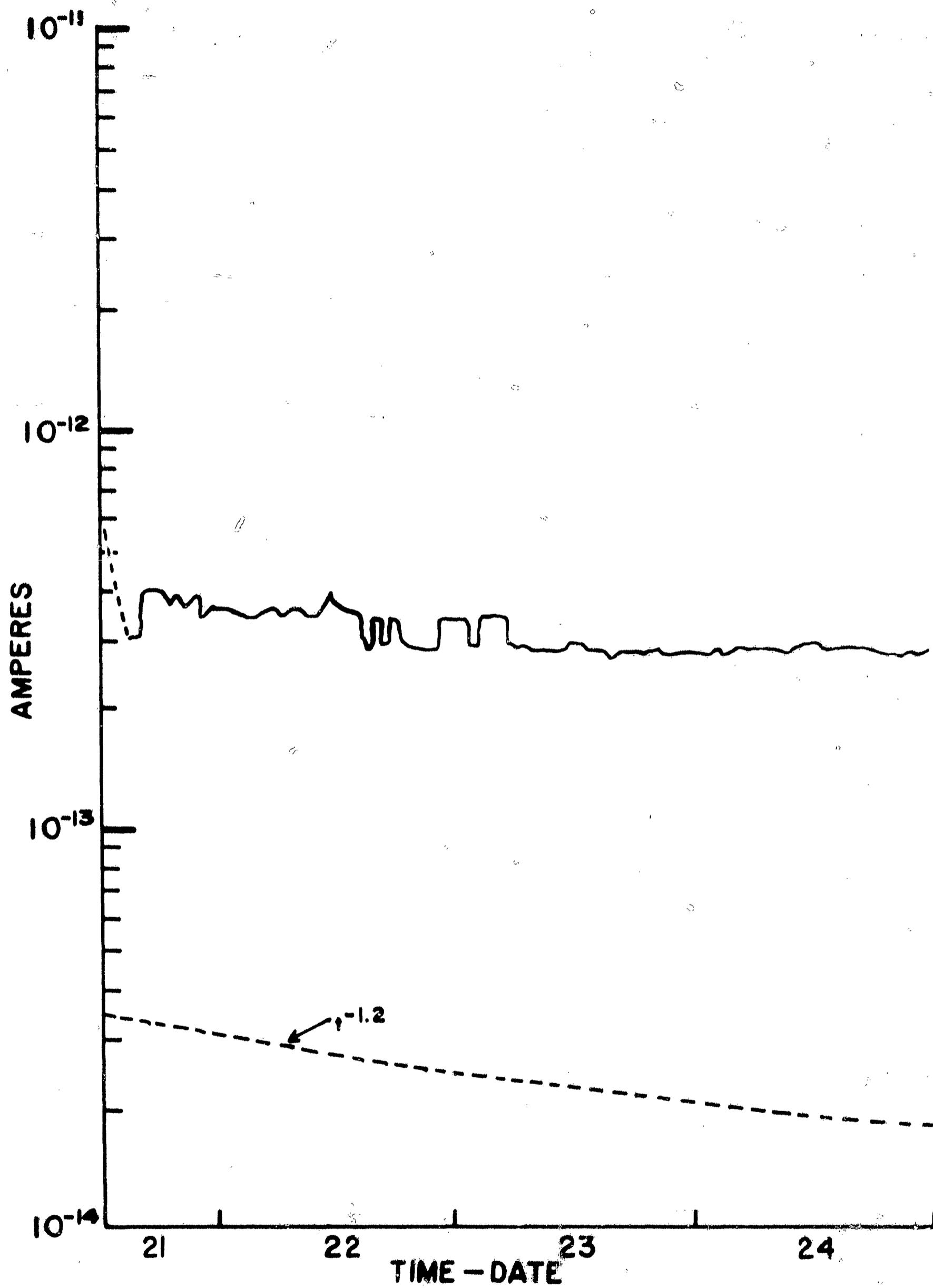


Figure 9. - Serial plot—sea-water intake monitor data. (Radiation intensity versus time.)

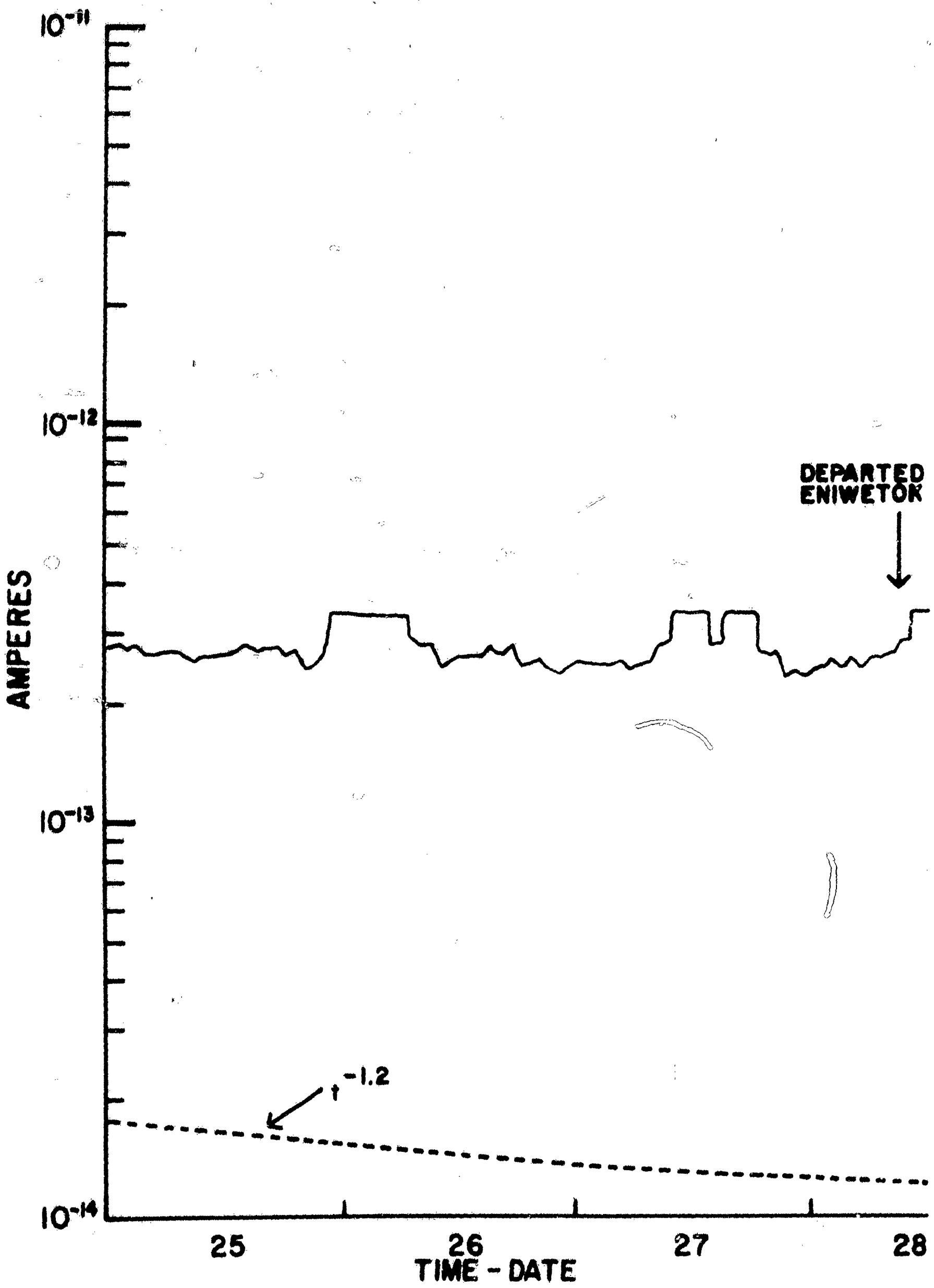


Figure 10. - Serial plot-sea-water intake monitor data. (Radiation intensity versus time.)

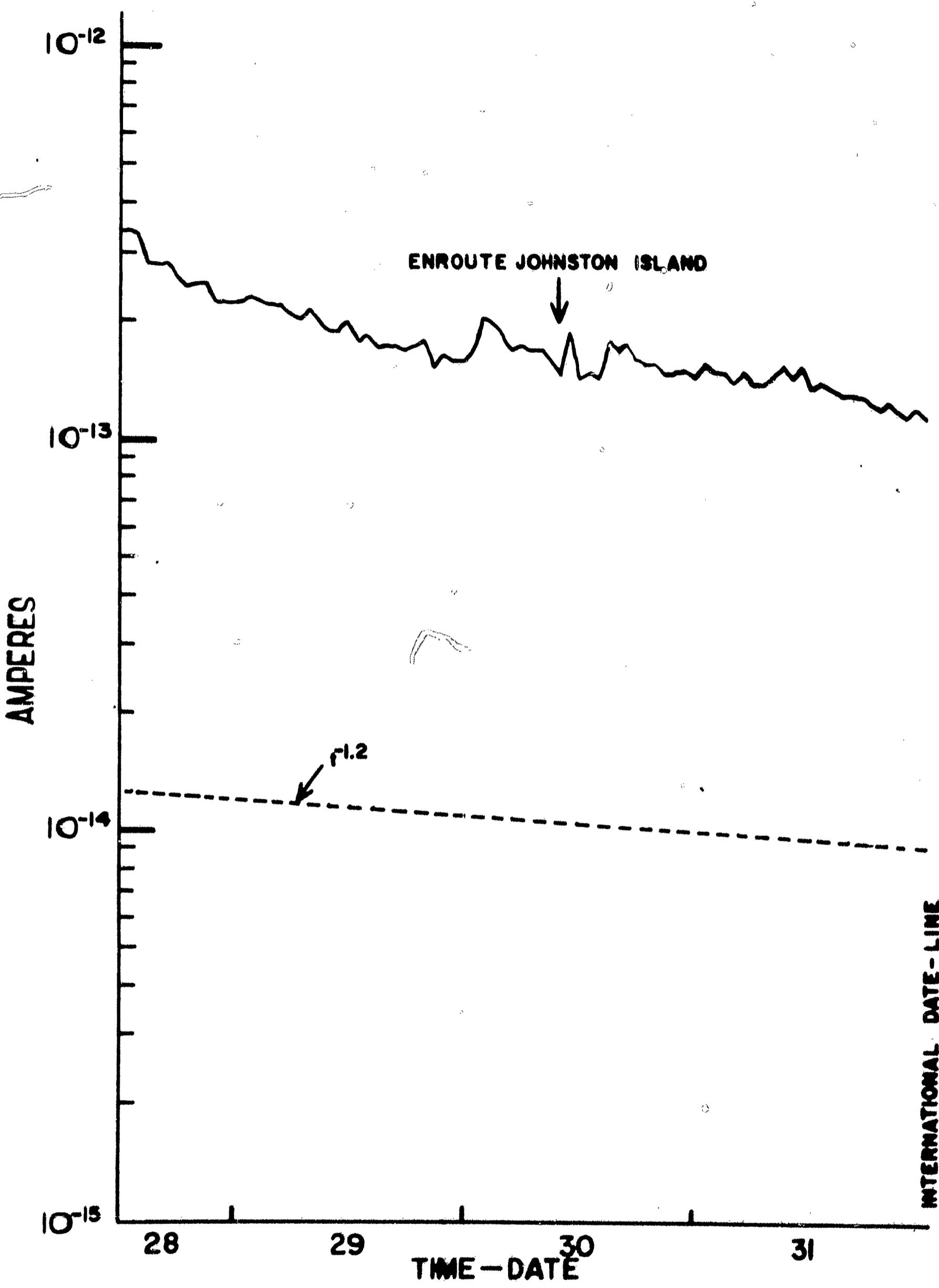


Figure 11. - Serial plot-sea-water intake monitor data. (Radiation intensity versus time.)

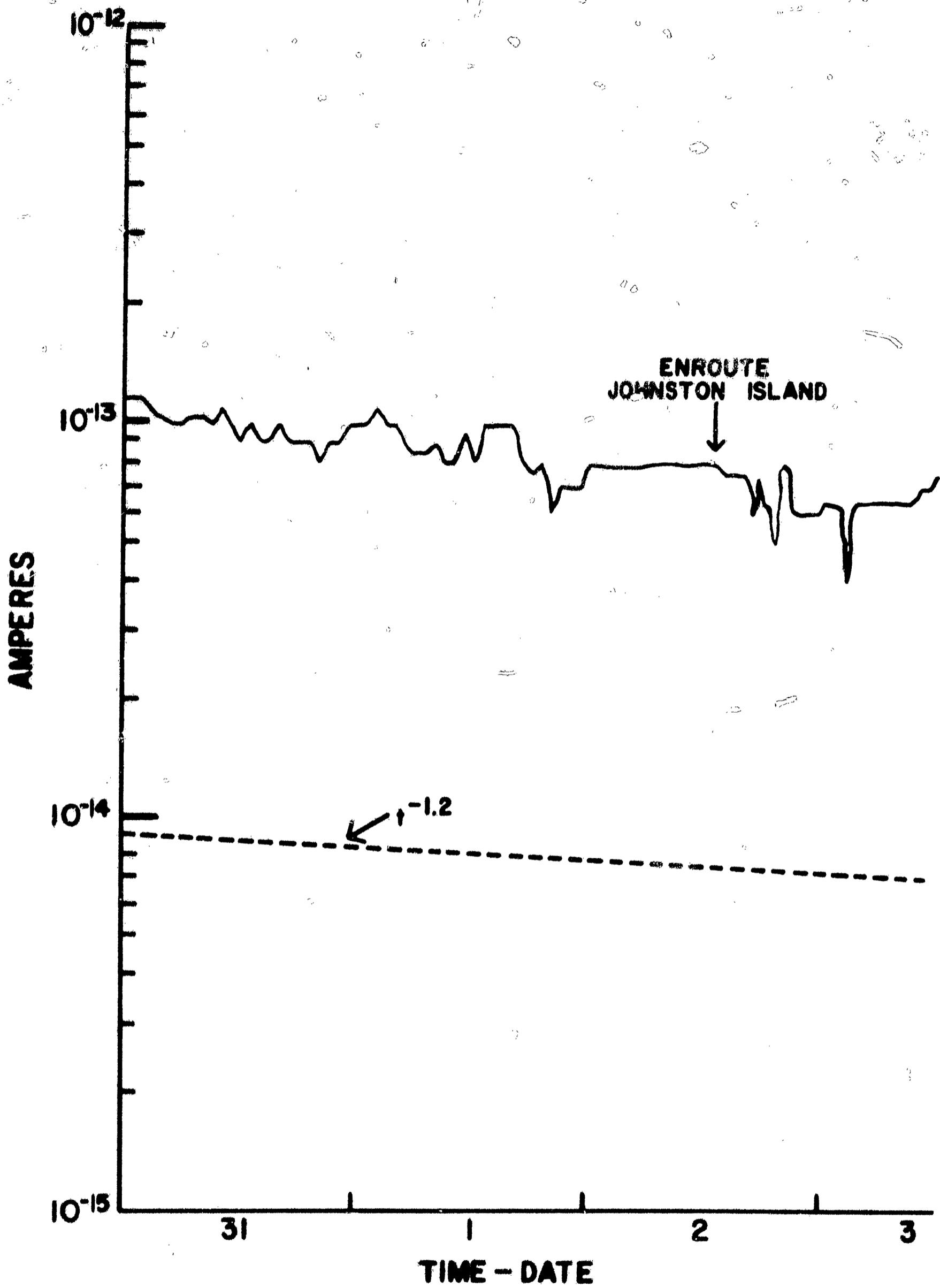


Figure 12. - Serial plot—sea-water intake monitor data. (Radiation intensity versus time.)

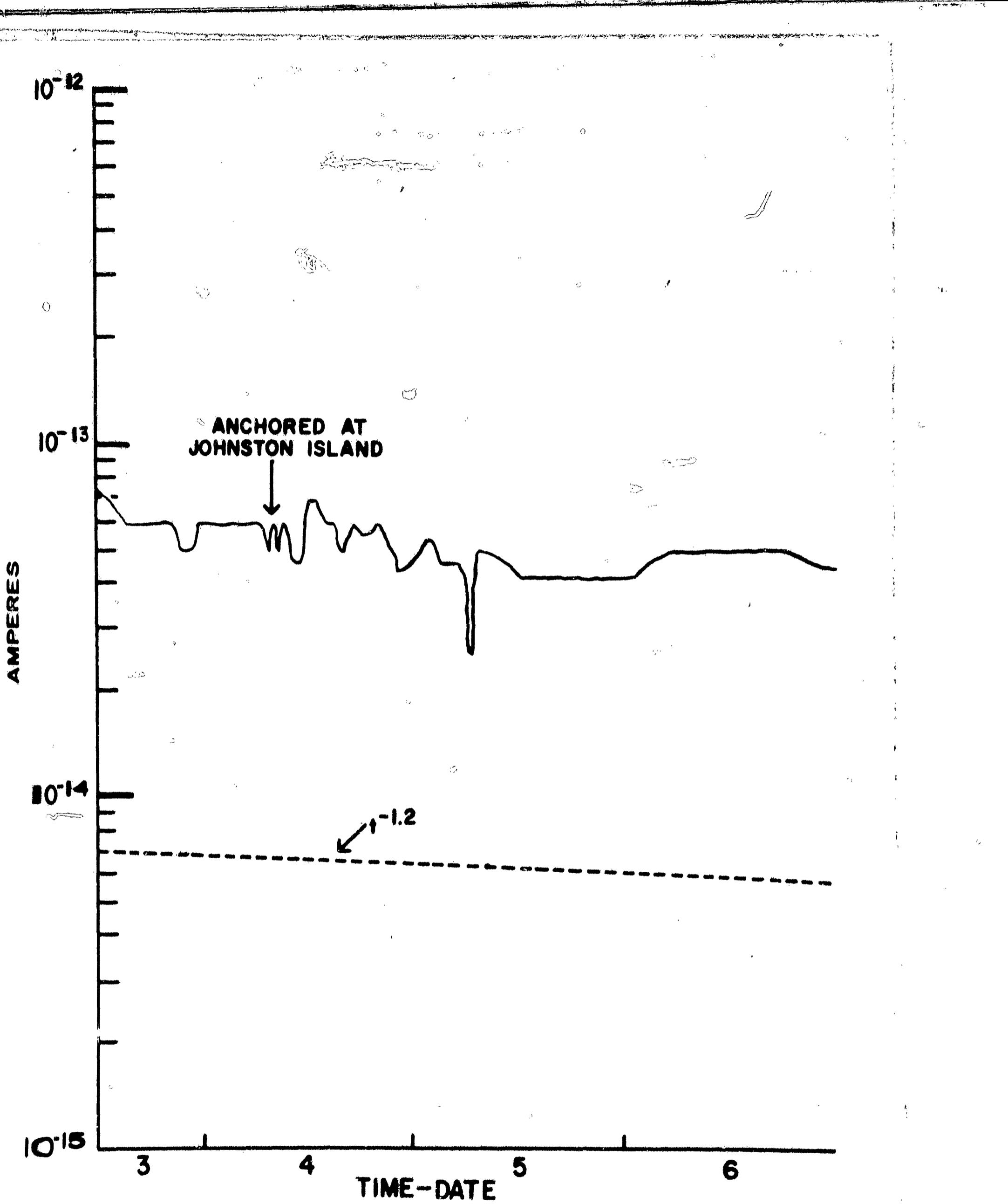


Figure 13. - Serial plot-sea-water intake monitor data. (Radiation intensity versus time.)

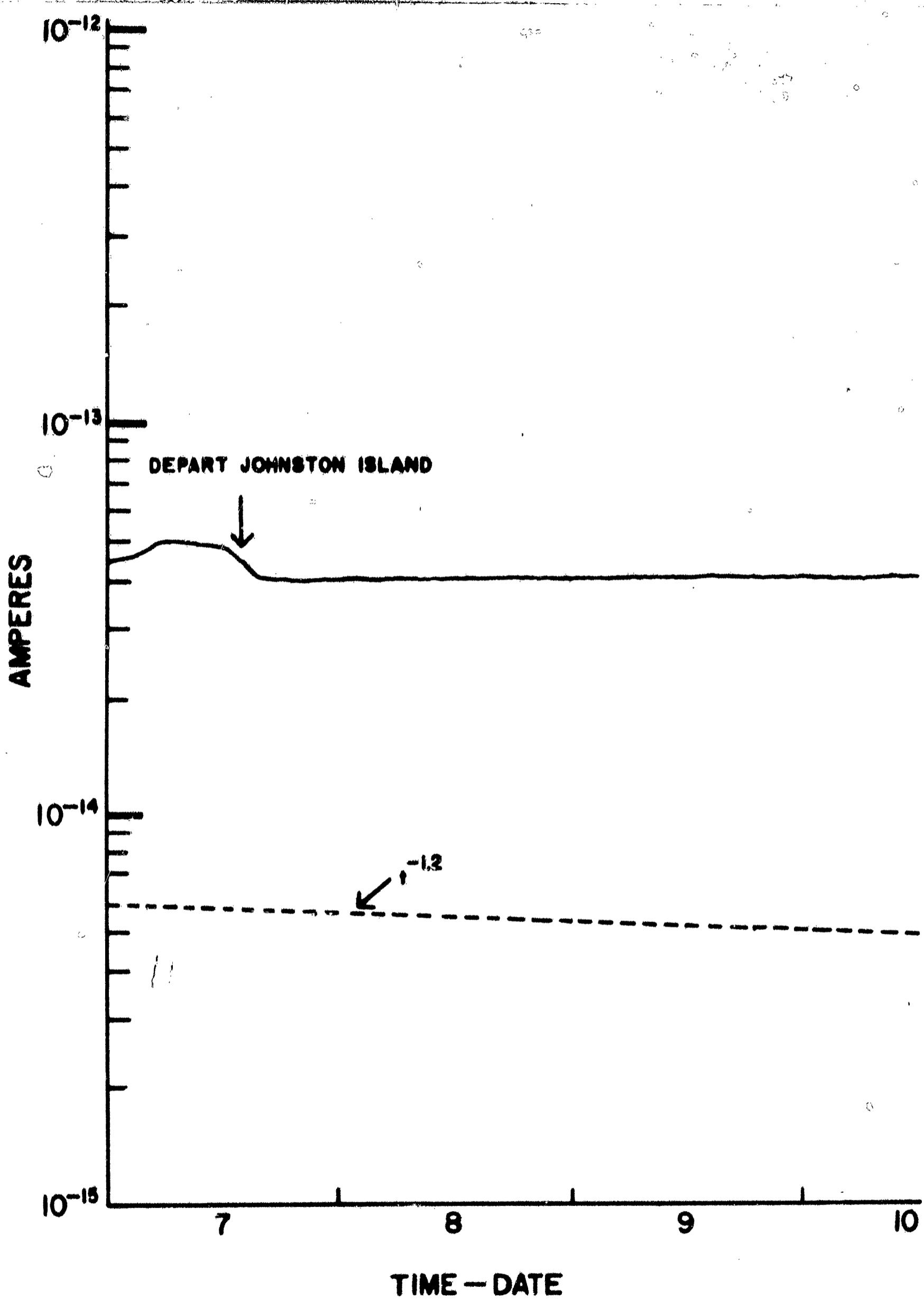


Figure 14. - Serial plot—sea-water intake monitor data. (Radiation intensity versus time.)

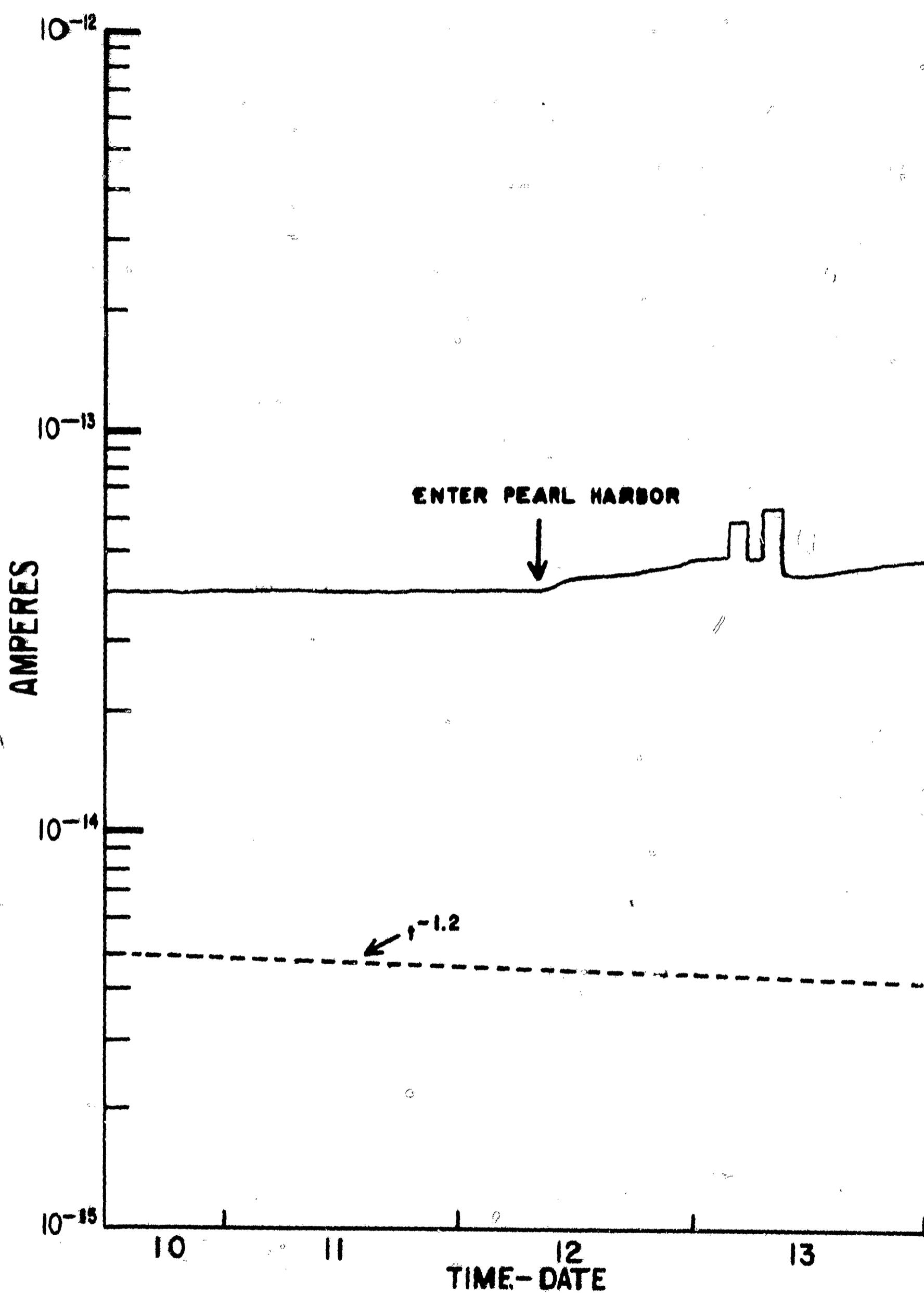


Figure 15. - Serial plot—sea-water intake monitor data. (Radiation intensity versus time.)

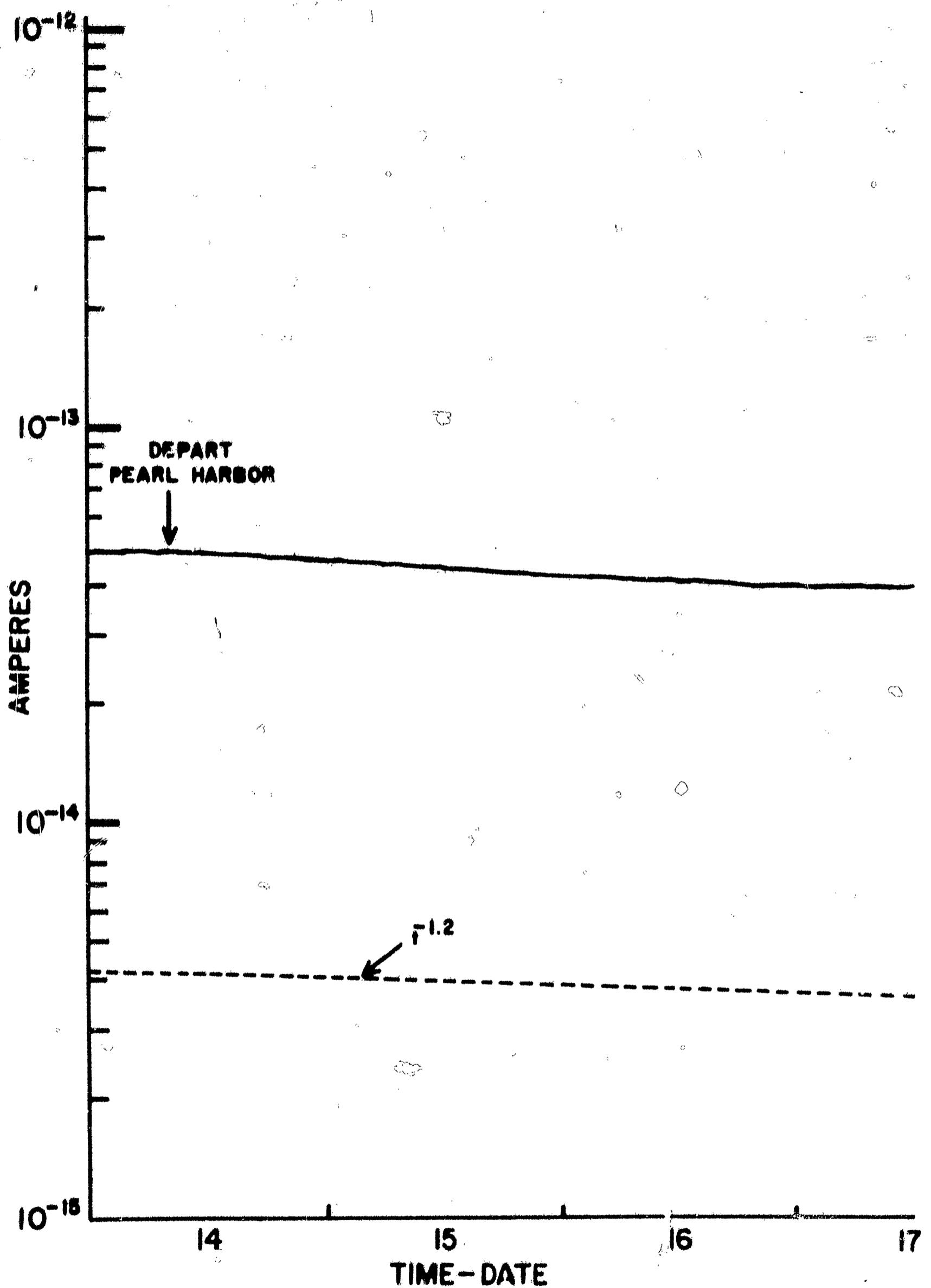


Figure 16. - Serial plot—sea-water intake monitor data. (Radiation intensity versus time.)

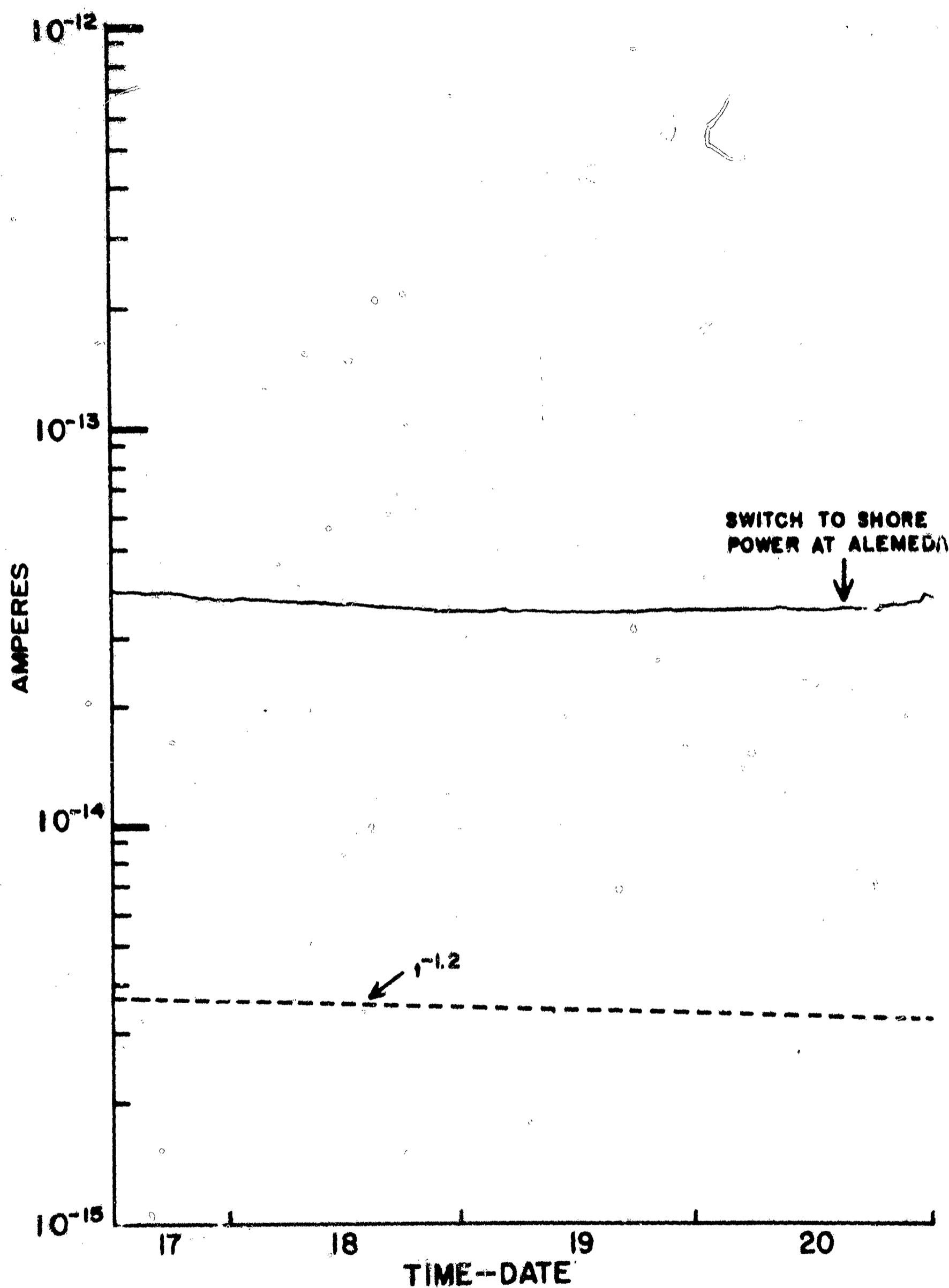


Figure 171 - Serial plot—sea-water intake monitor data. (Radiation intensity versus time.)

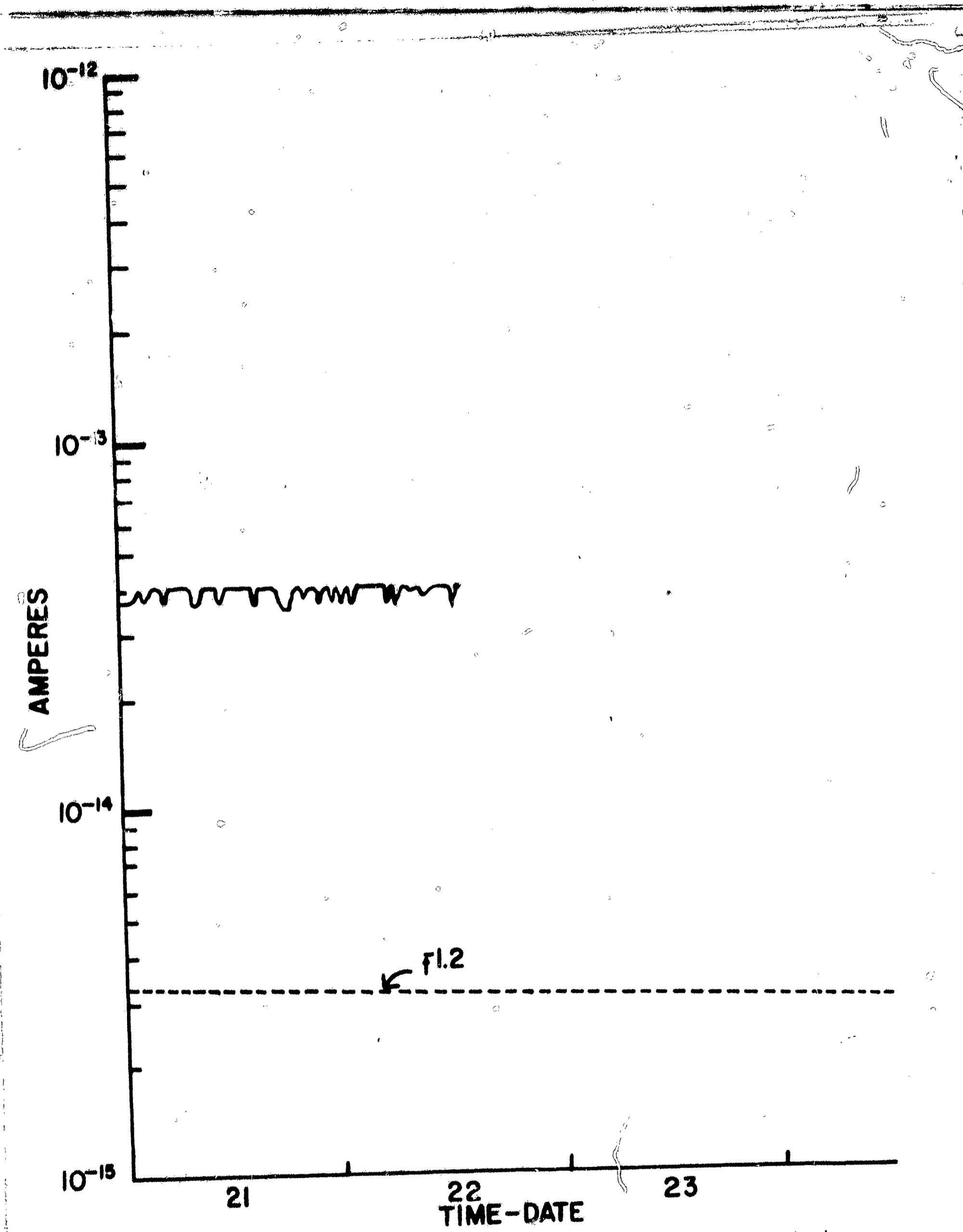


Figure 18. - Serial plot—sea-water intake monitor data. (Radiation intensity versus time.)

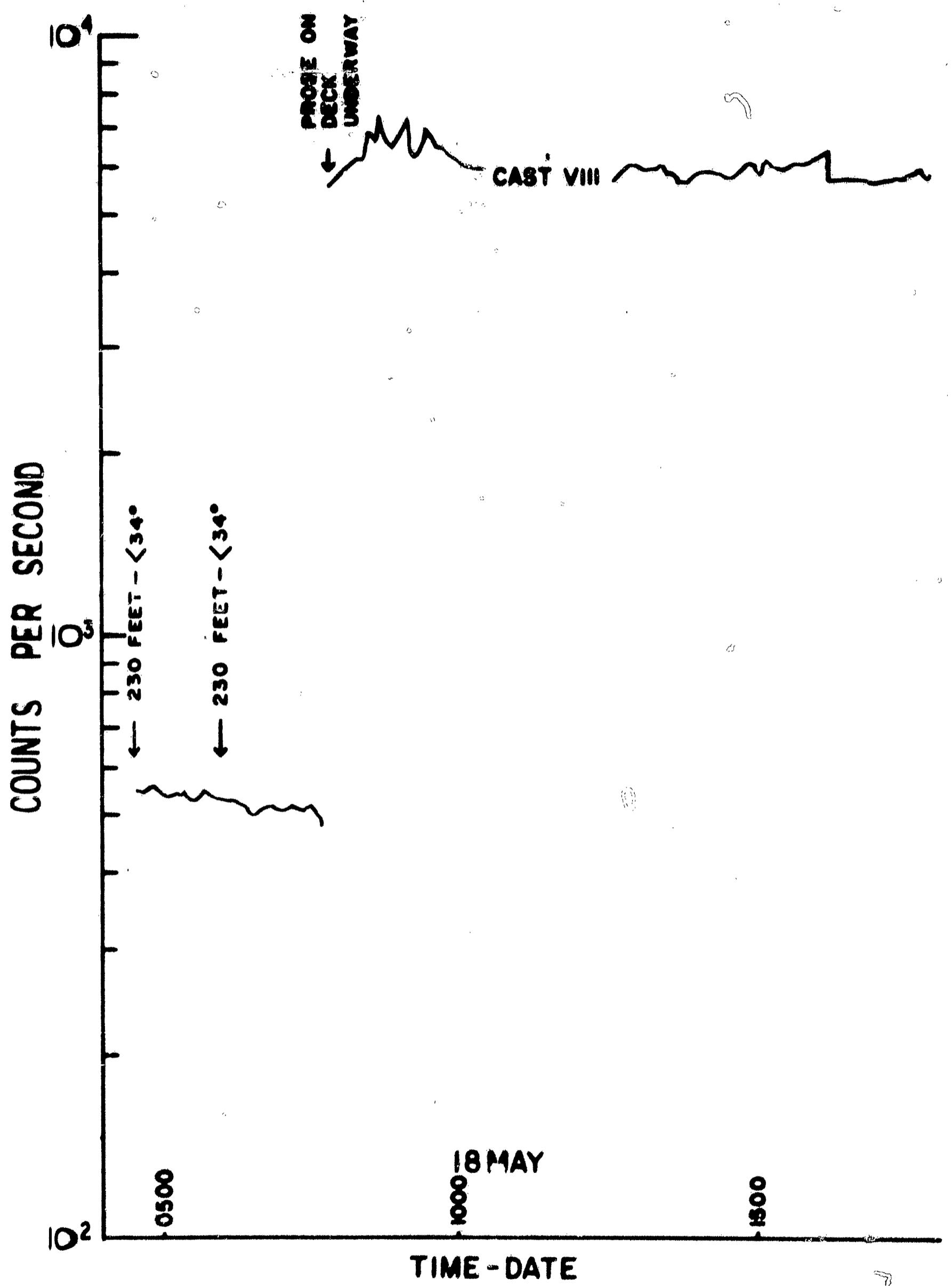


Figure 19. - Serial plot—scintillation probe data. (Radiation intensity versus time.)

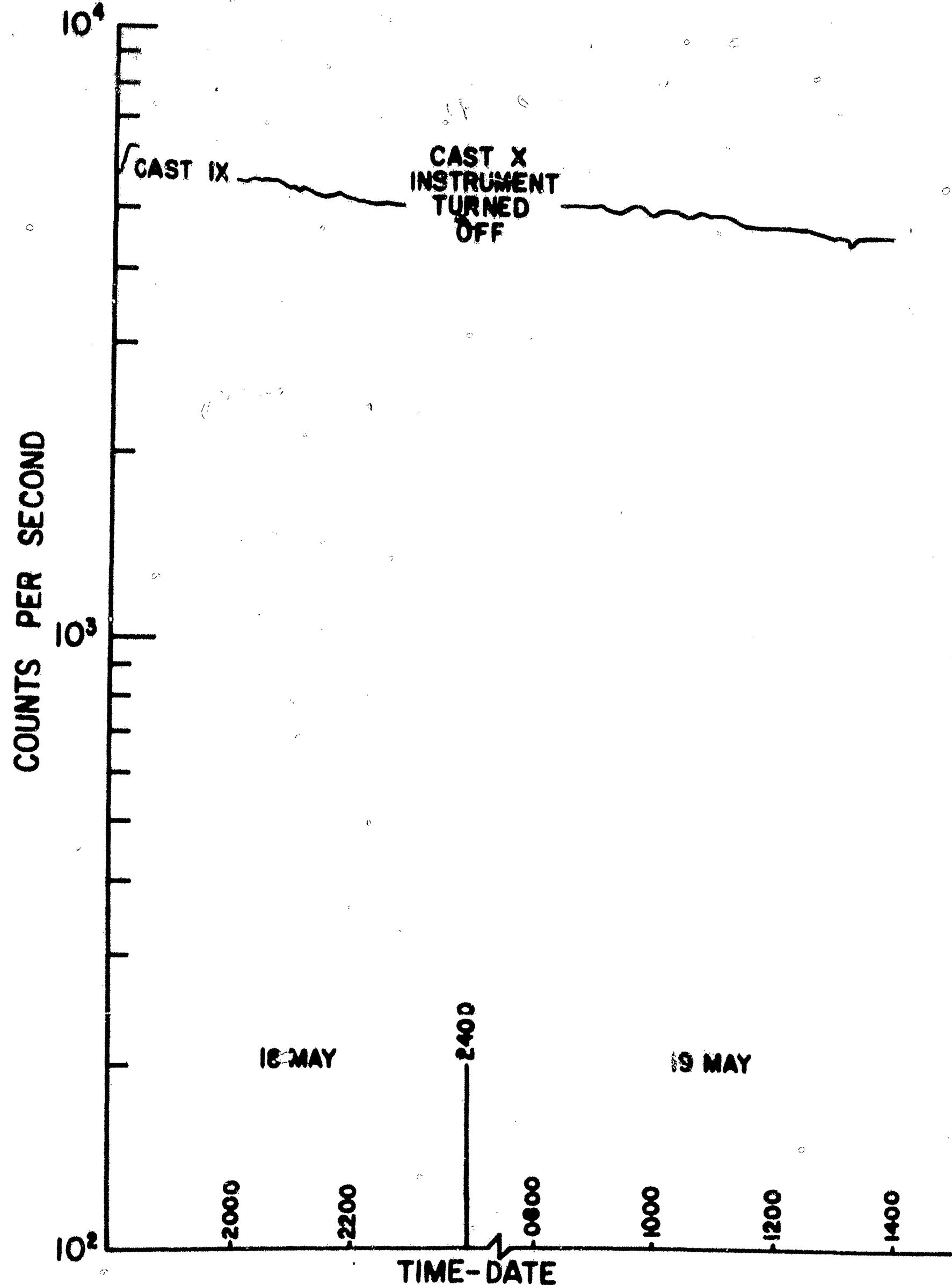


Figure 20. - Serial plot—scintillation probe data. (Radiation intensity versus time.)

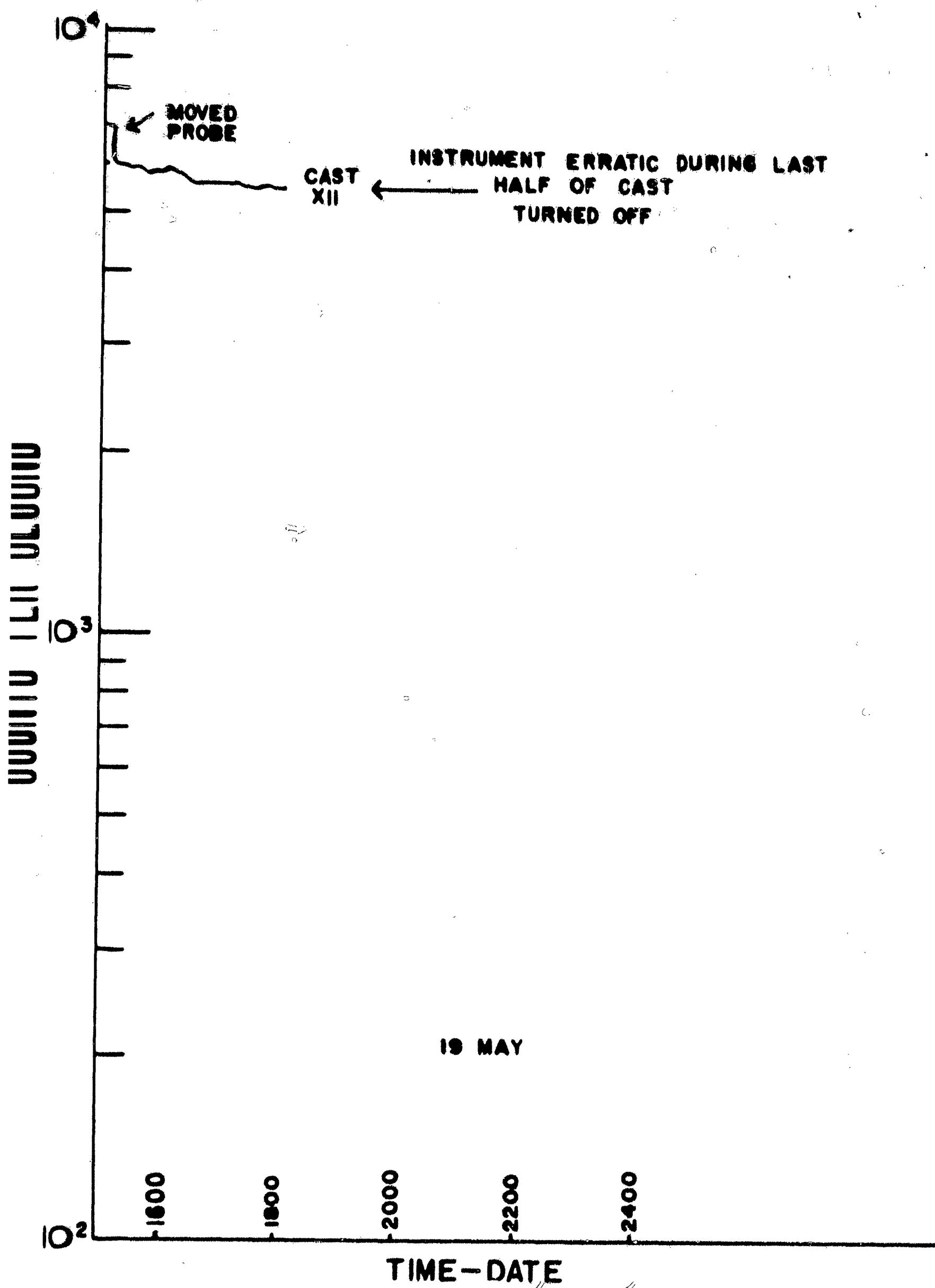


Figure 21. - Serial plot—scintillation probe data. (Radiation intensity versus time.)

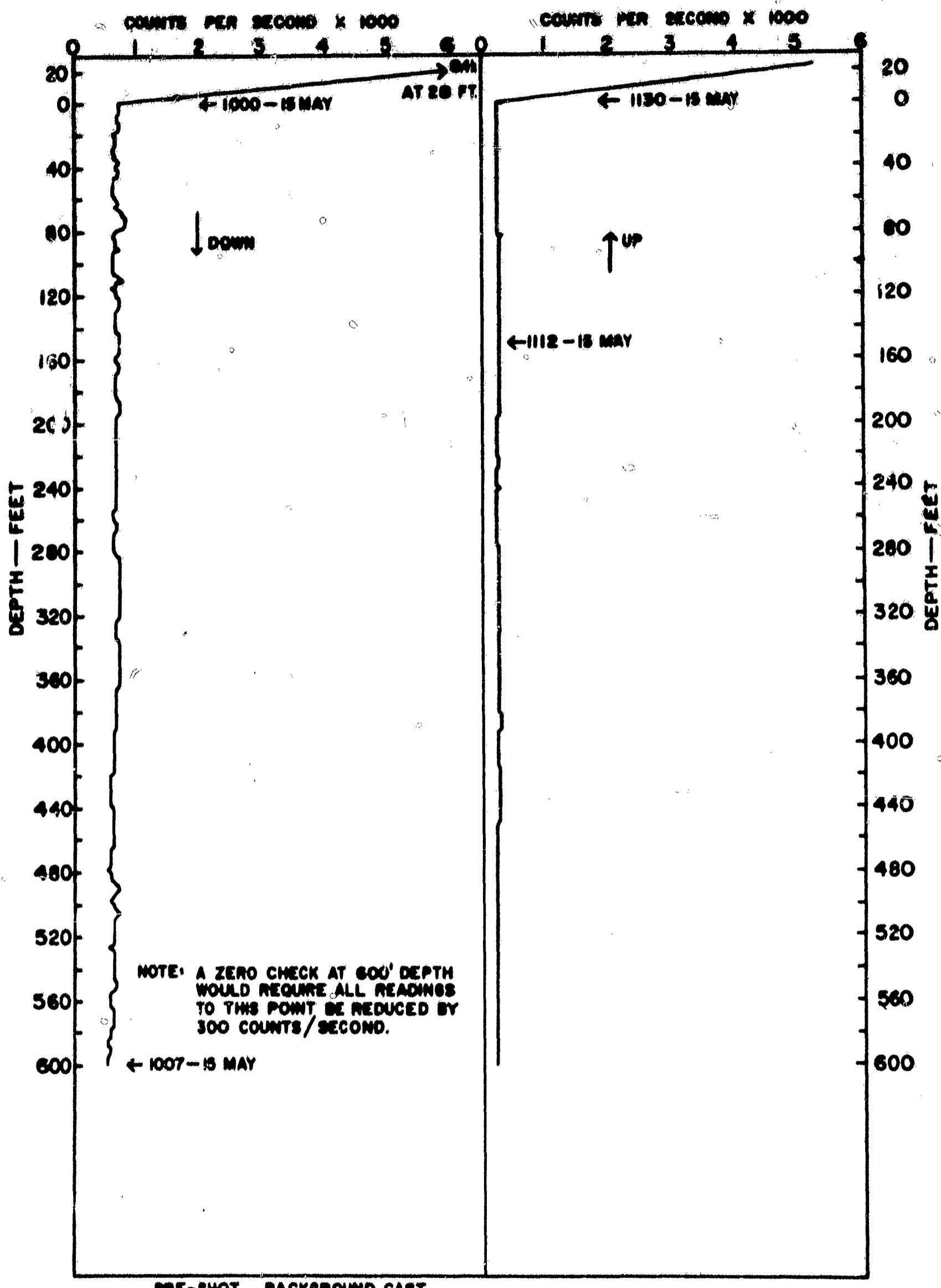


Figure 22. - Radiation intensity τ_{eff} depth-background cast.

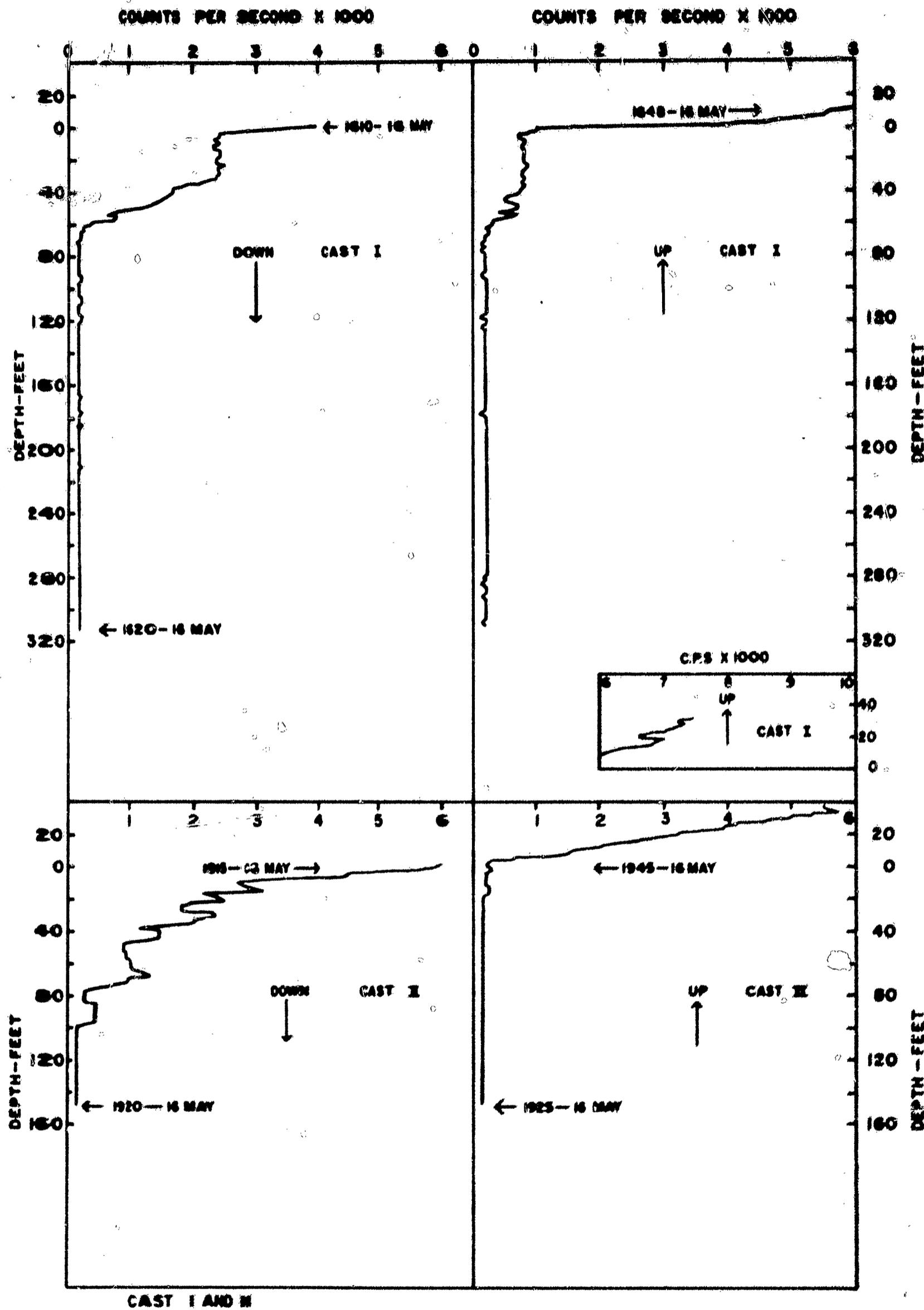
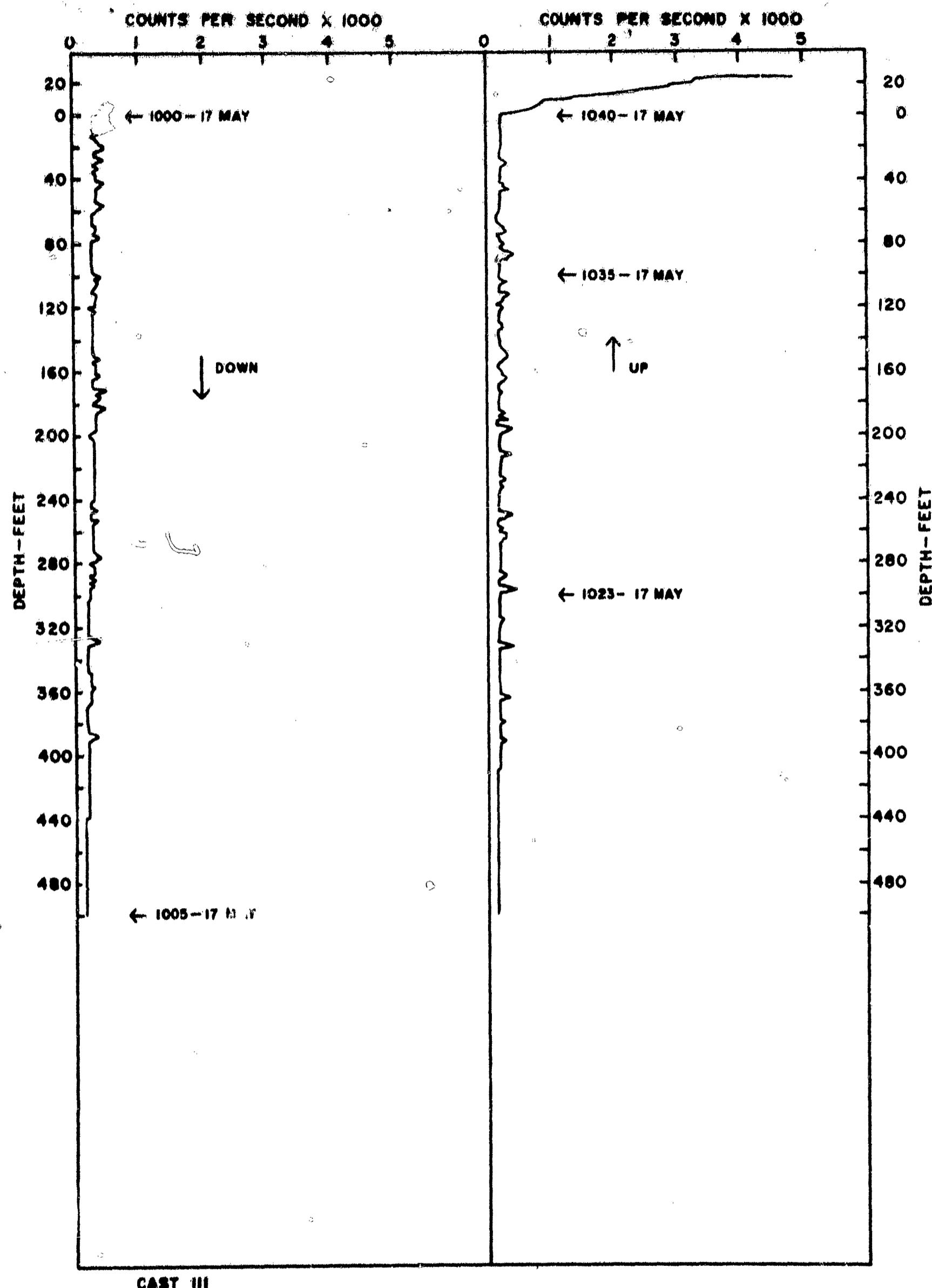
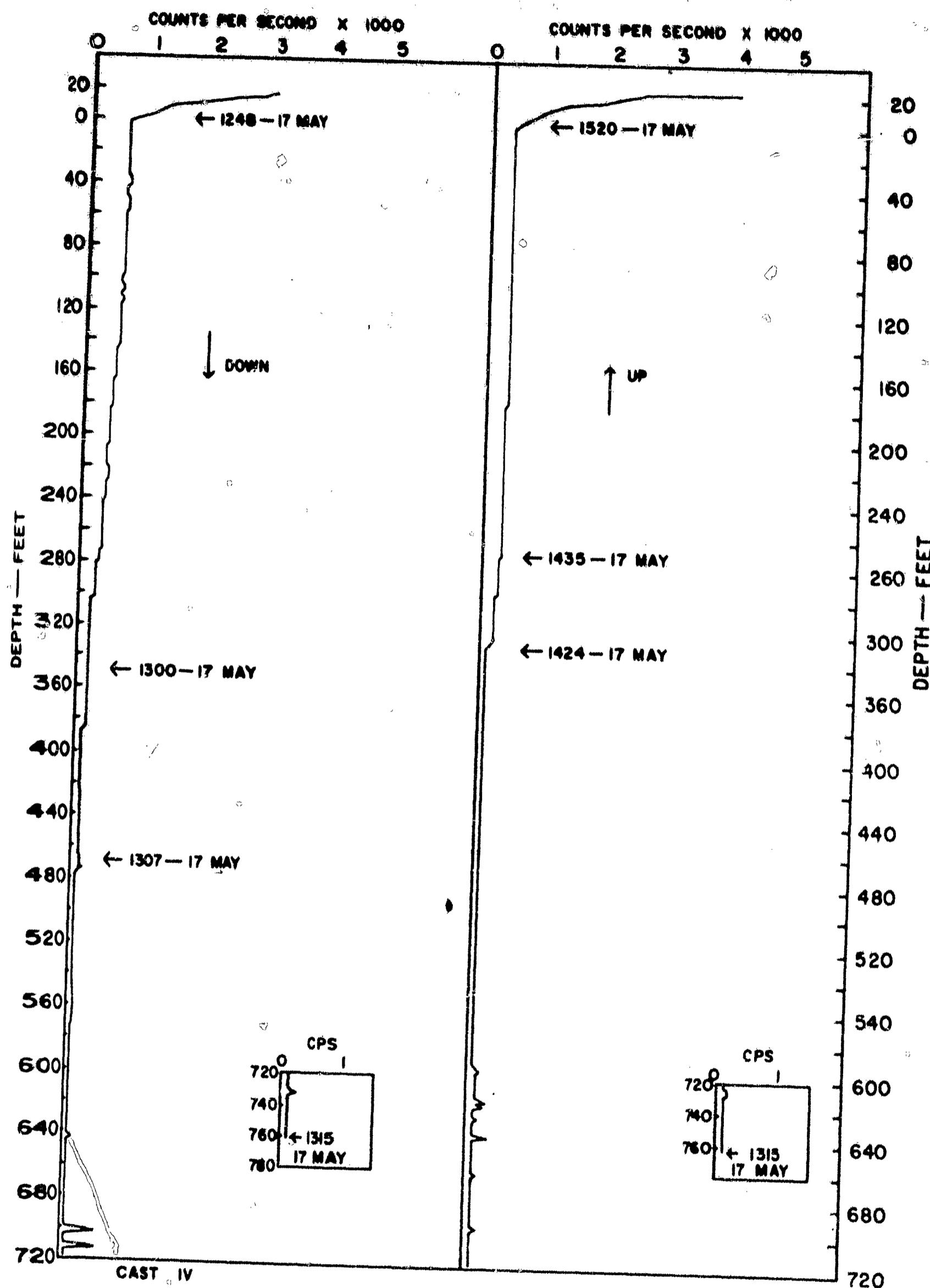


Figure 23. - Radiation intensity versus depth—cast I and II.



RADIATION INTENSITY VERSUS DEPTH
Figure 24. - Radiation intensity versus depth—cast III.



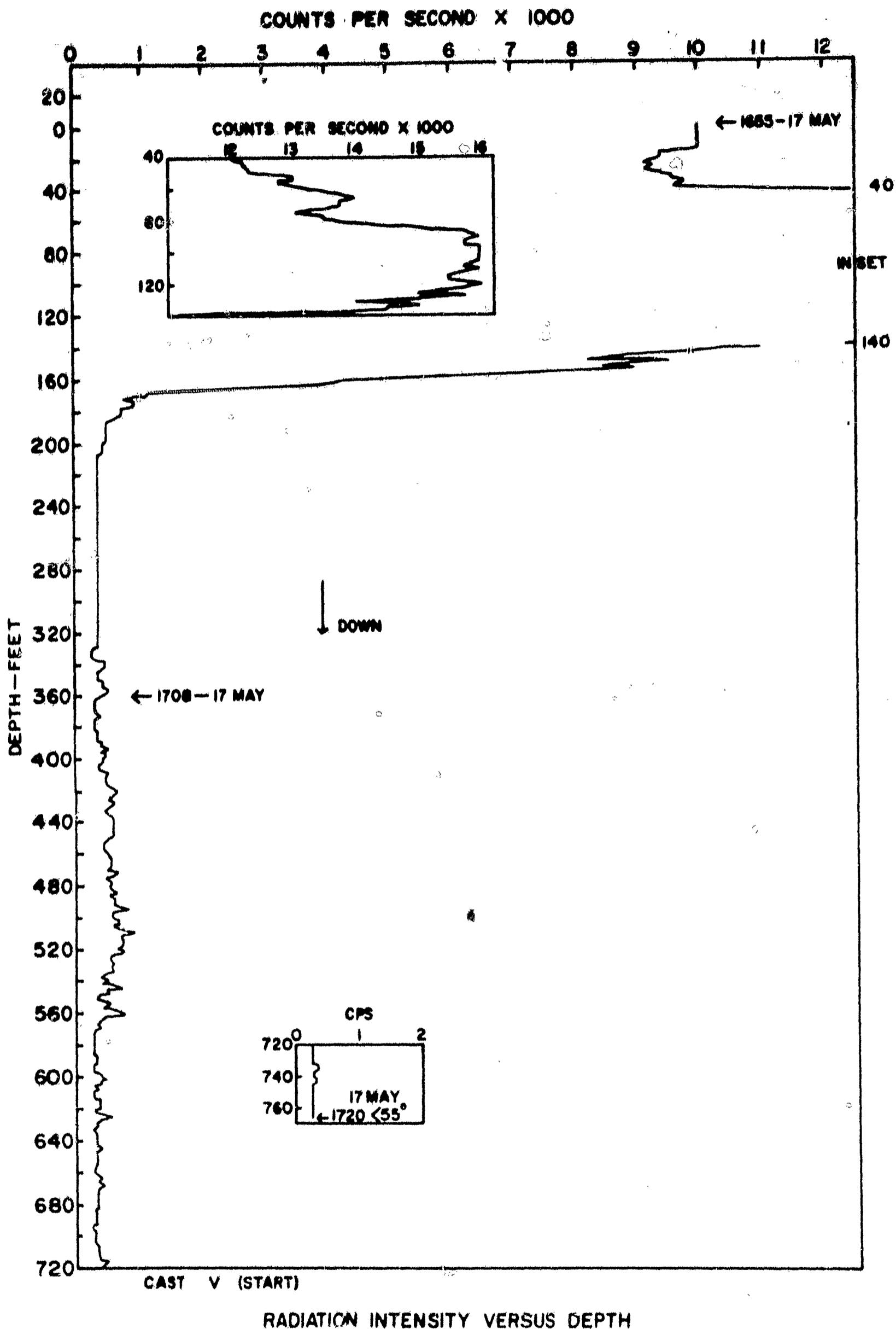


Figure 26. - Radiation intensity versus depth -cast V (start).

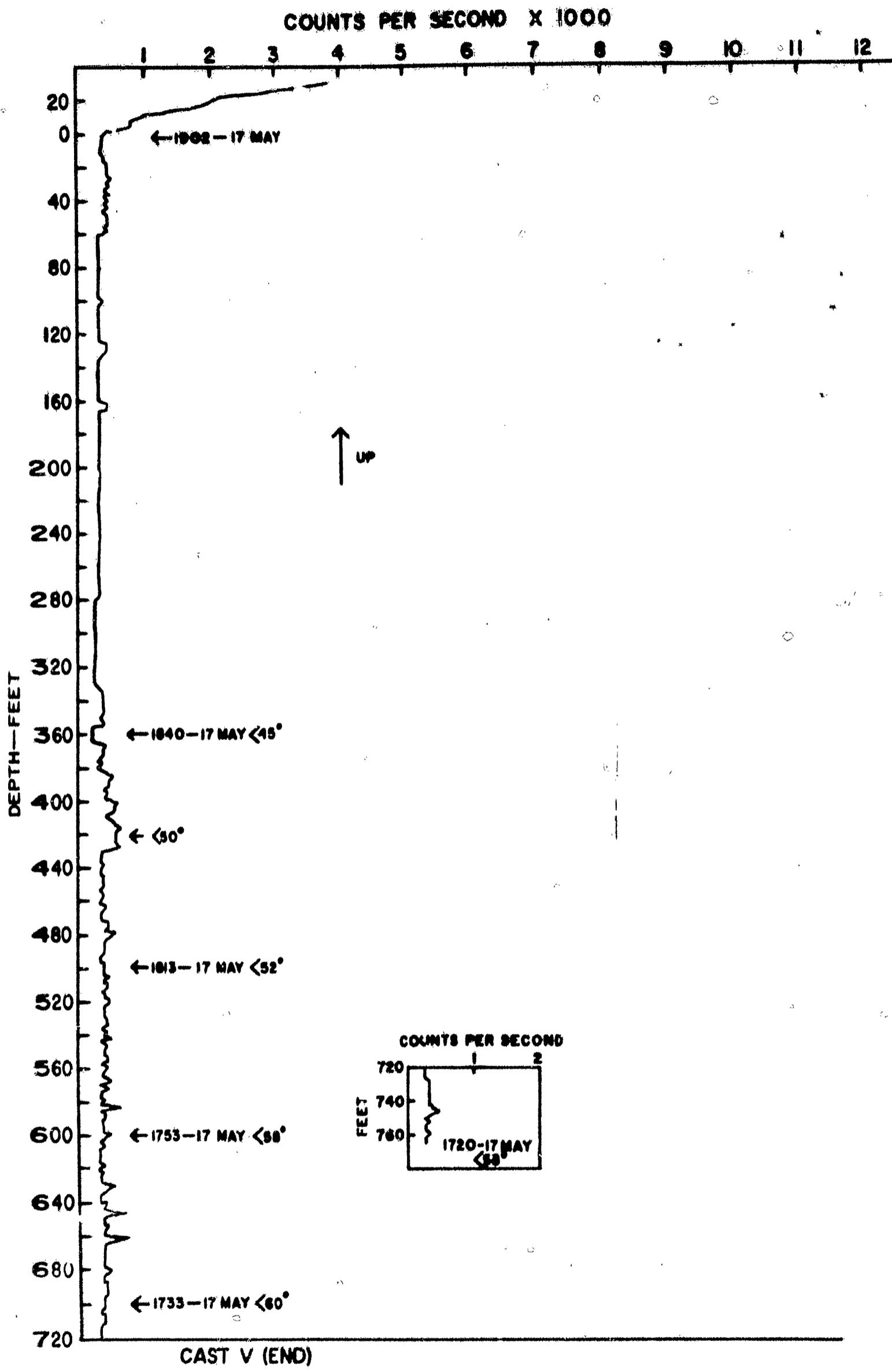


Figure 27. Radiation intensity versus depth—cast V (end).

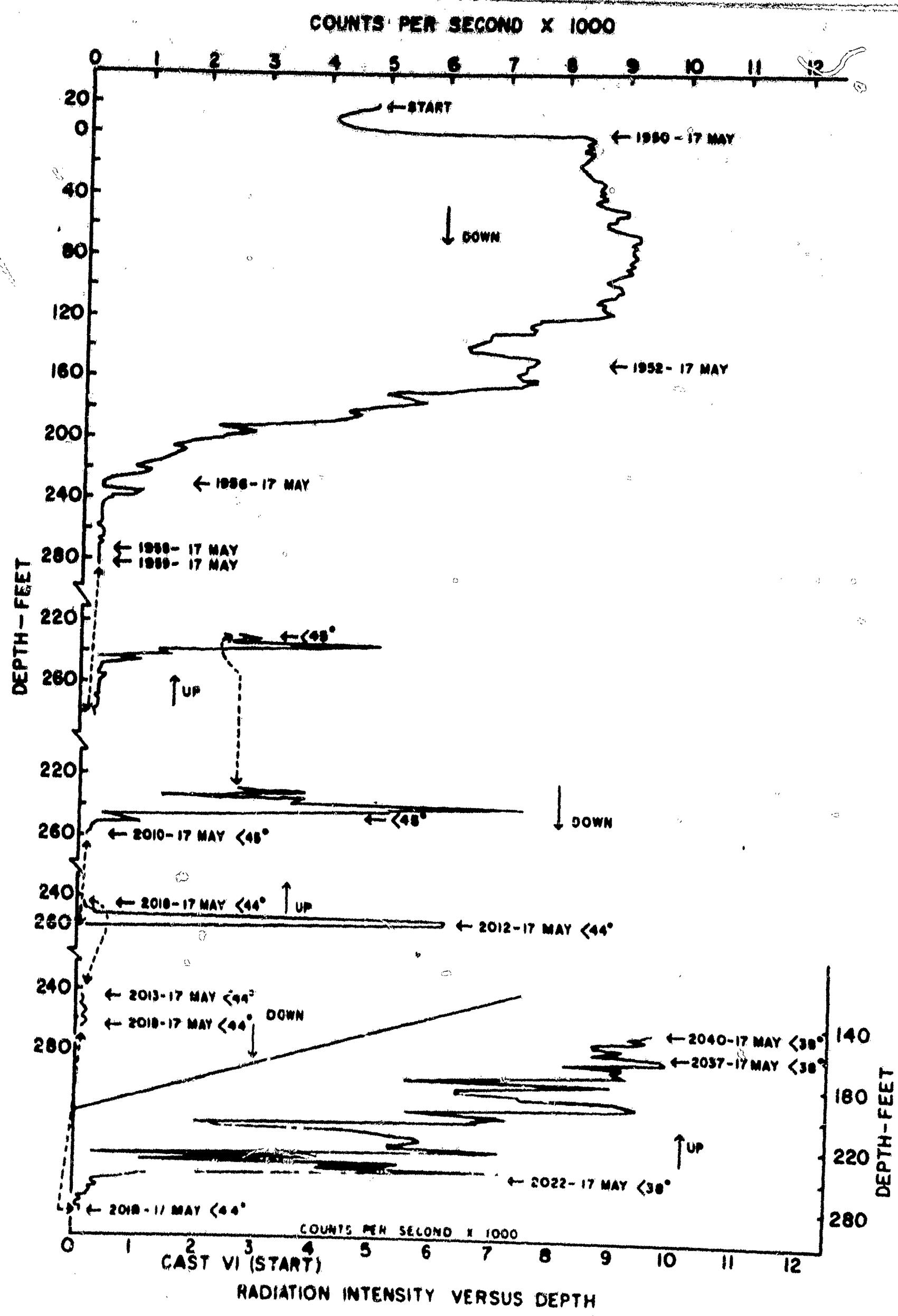
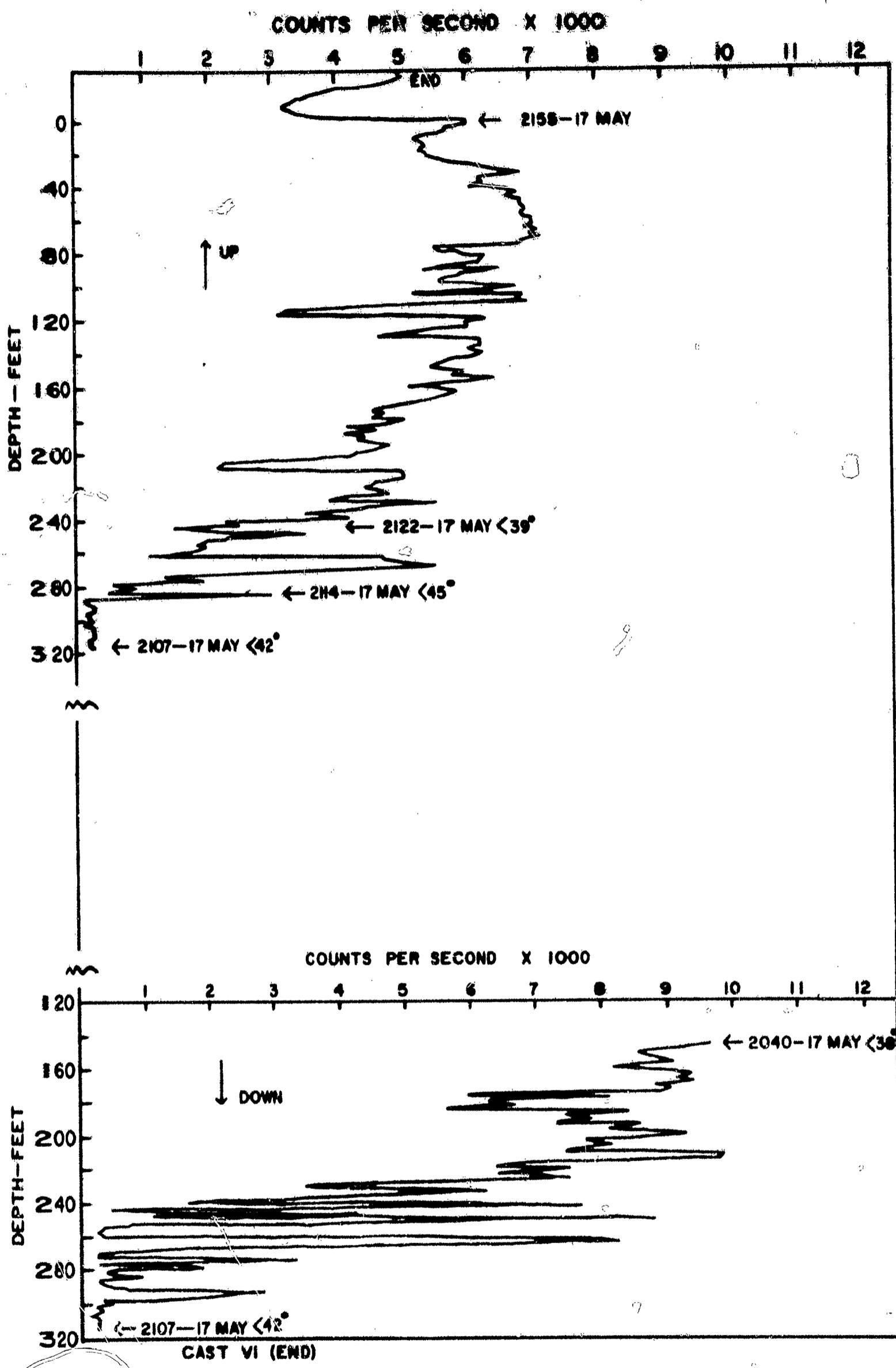
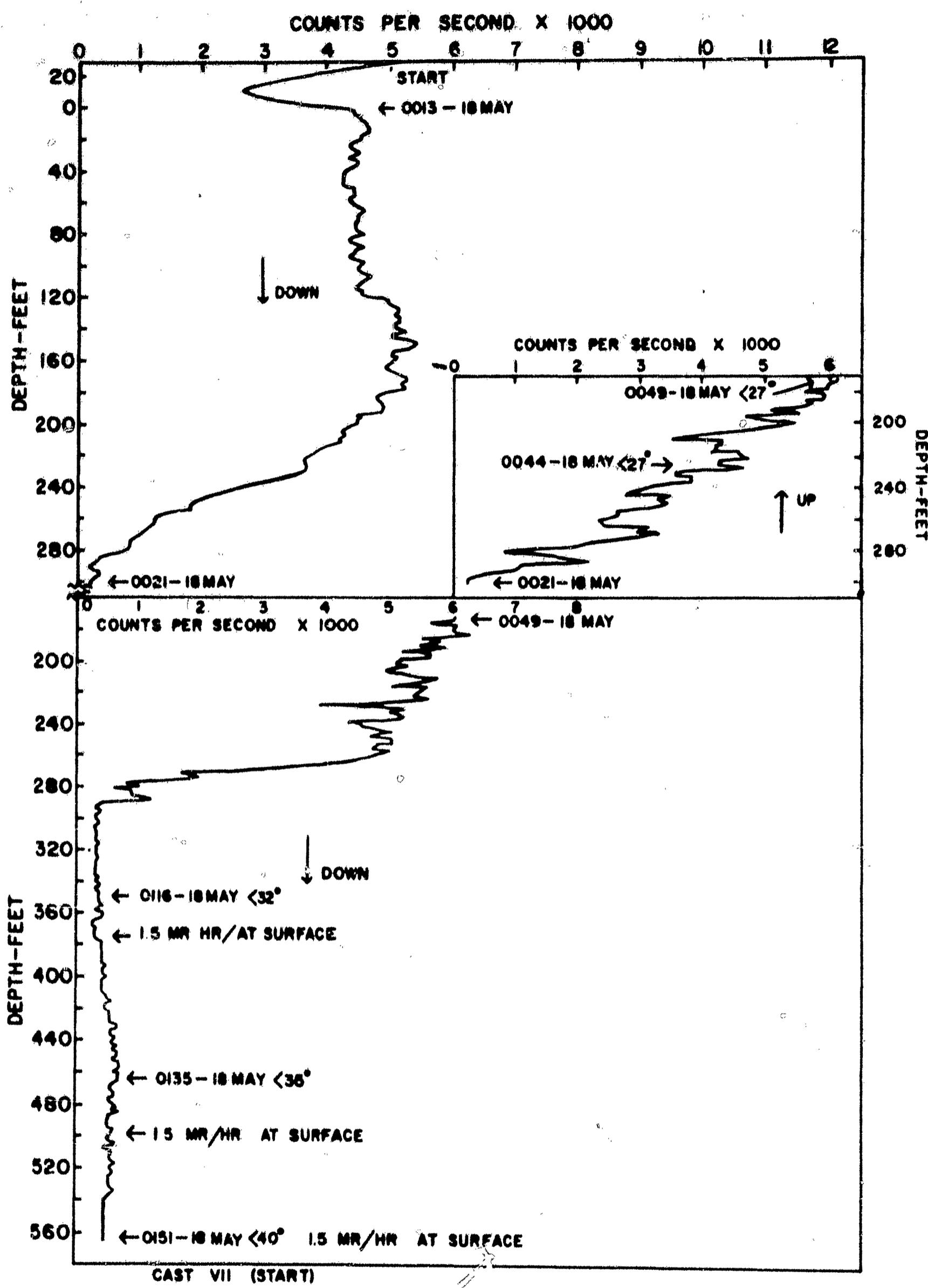


Figure 28. - Radiation intensity versus depth—cast VI (start).

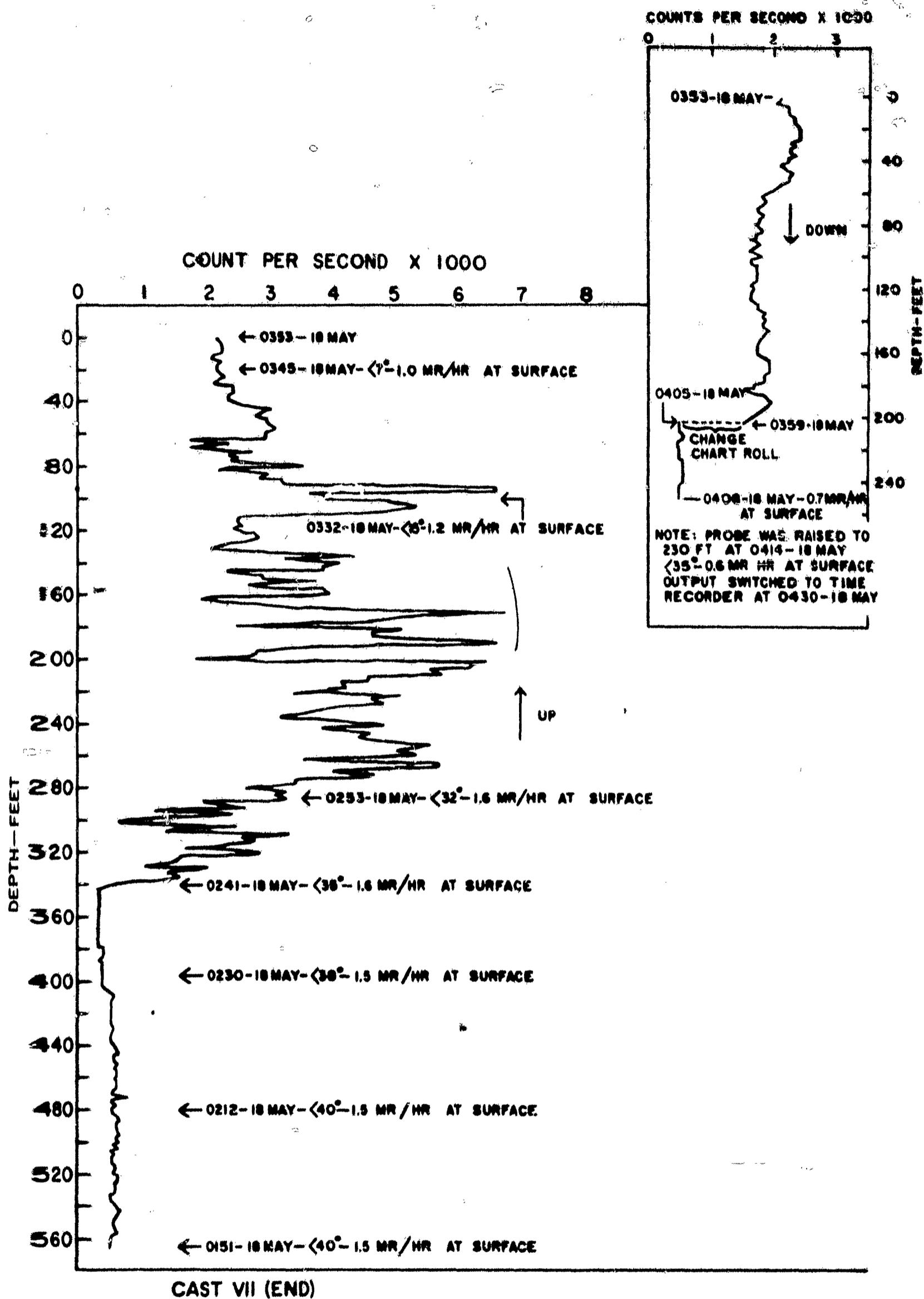


RADIATION INTENSITY VERSUS DEPTH

Figure 29. - Radiation intensity versus depth—cast VI (end).



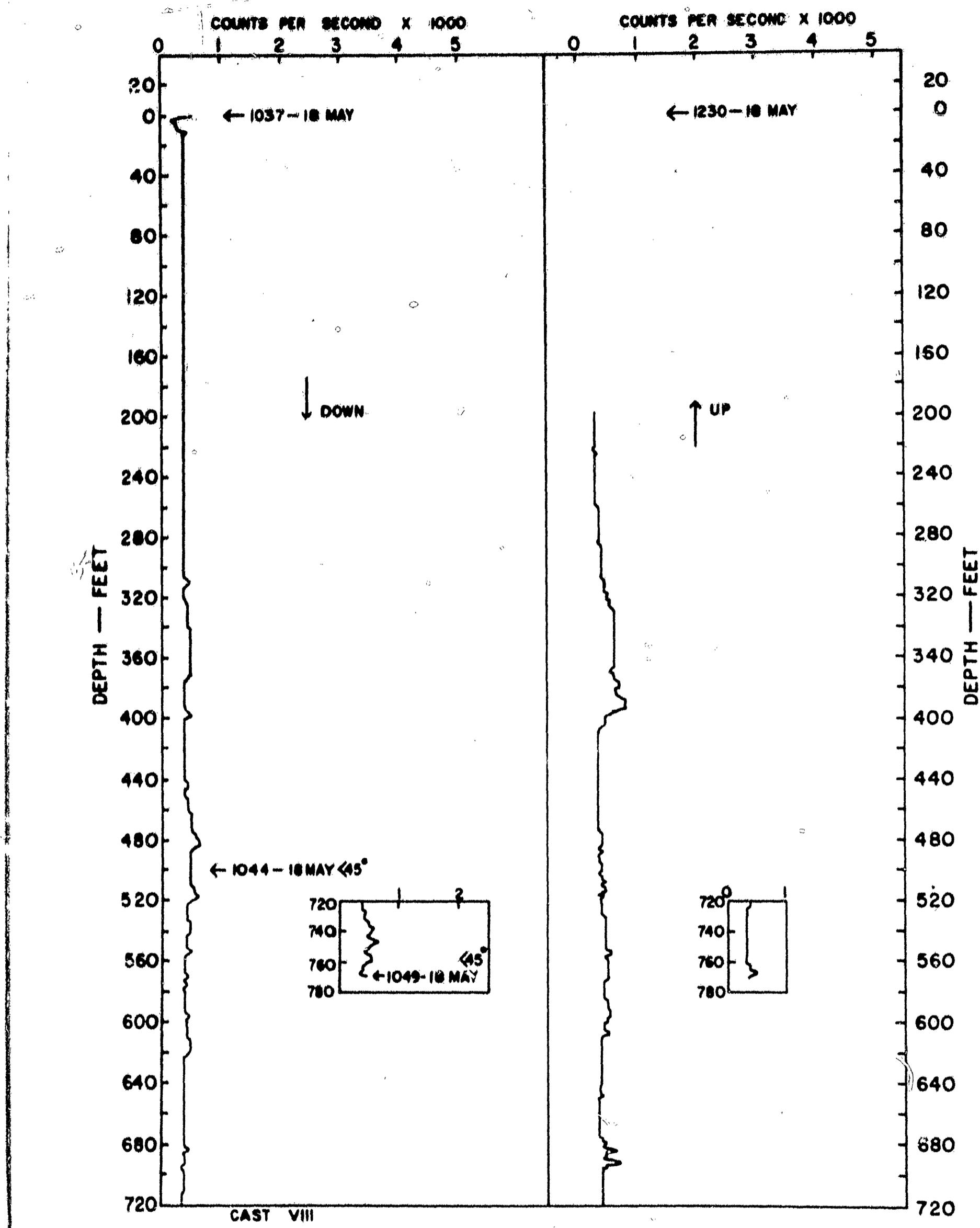
RADIATION INTENSITY VERSUS DEPTH
Figure 30. - Radiation intensity versus depth—cast VII (start).

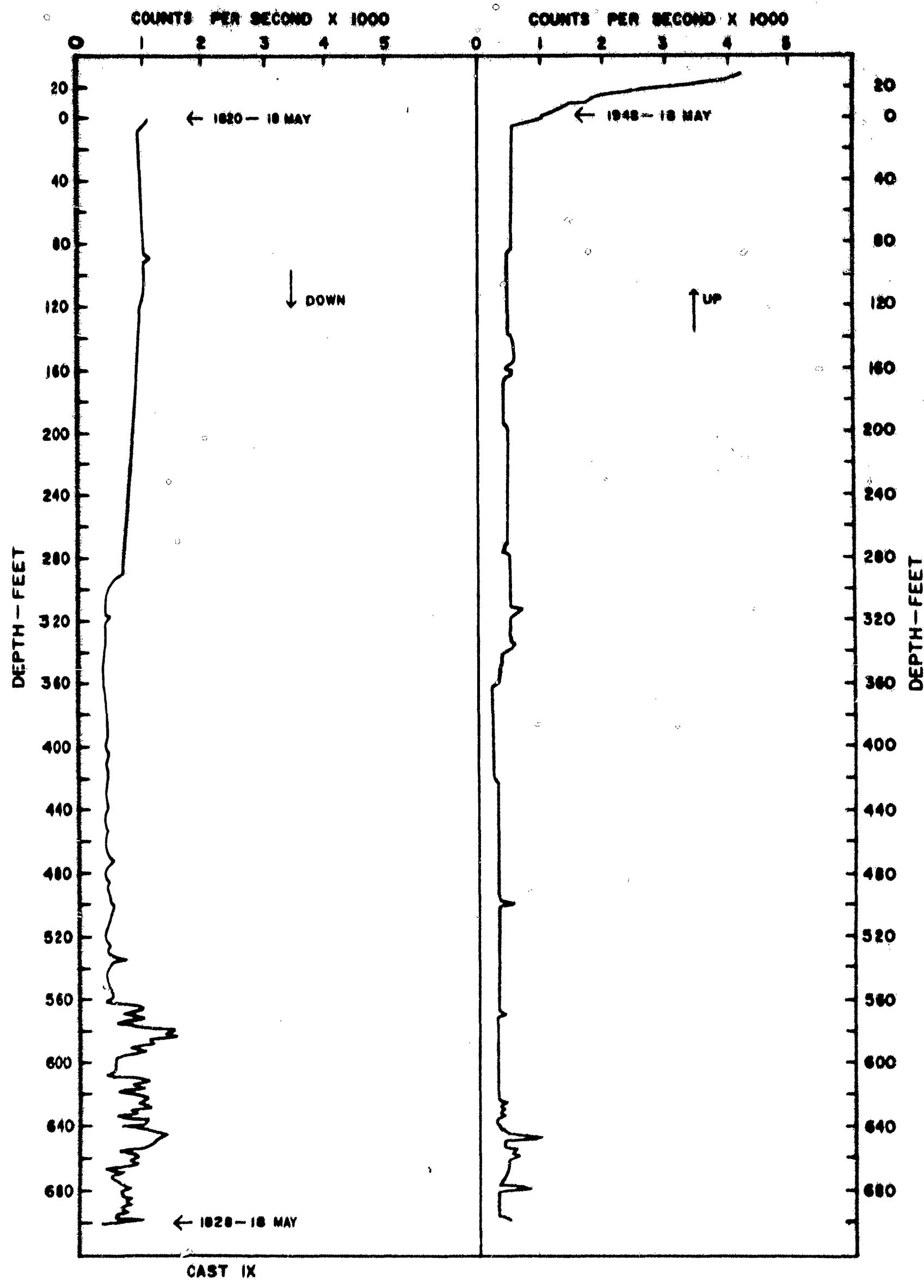


CAST VII (END)

RADIATION INTENSITY VERSUS DEPTH

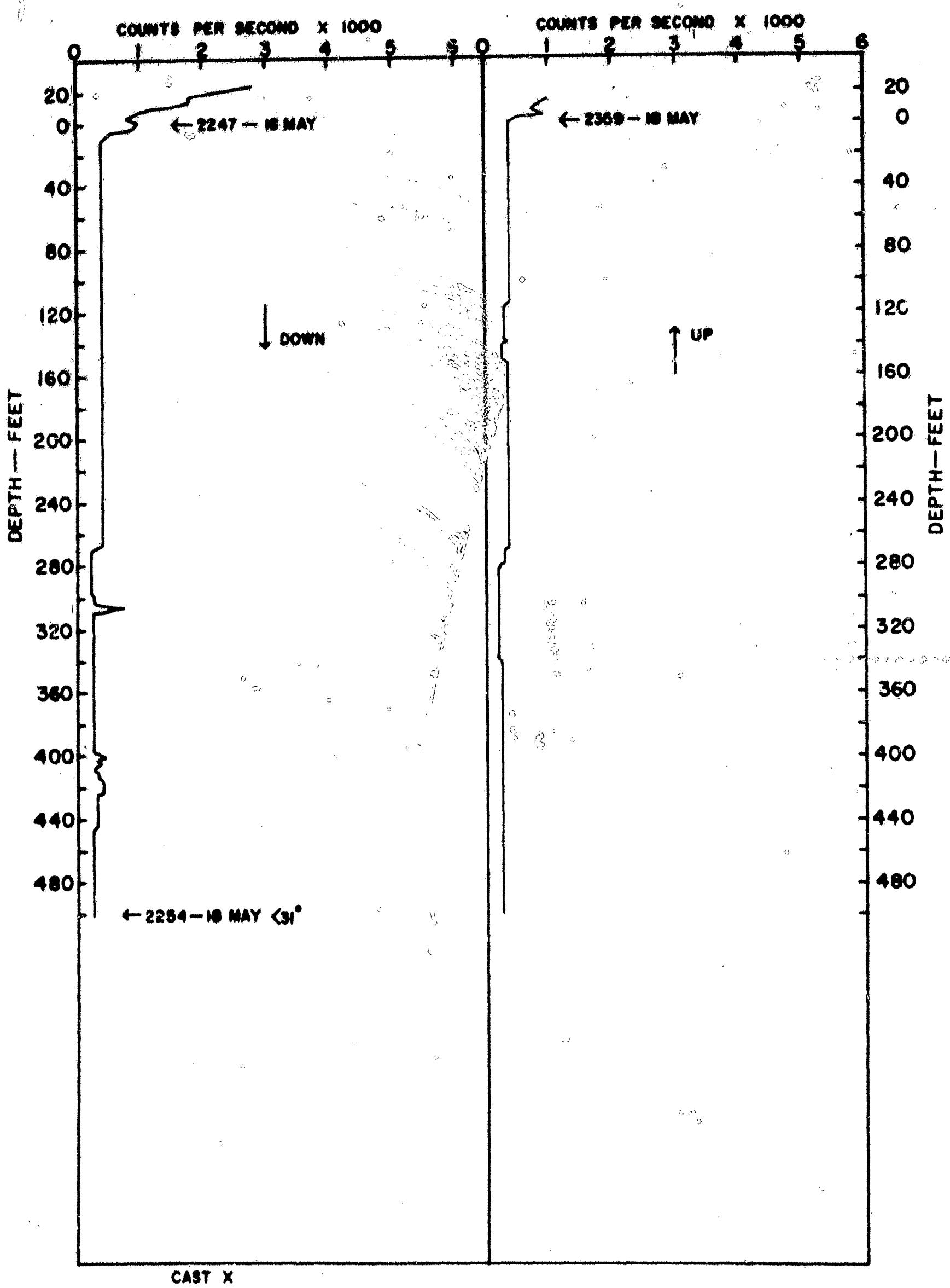
Figure 31. - Radiation intensity versus depth—cast VII (end).

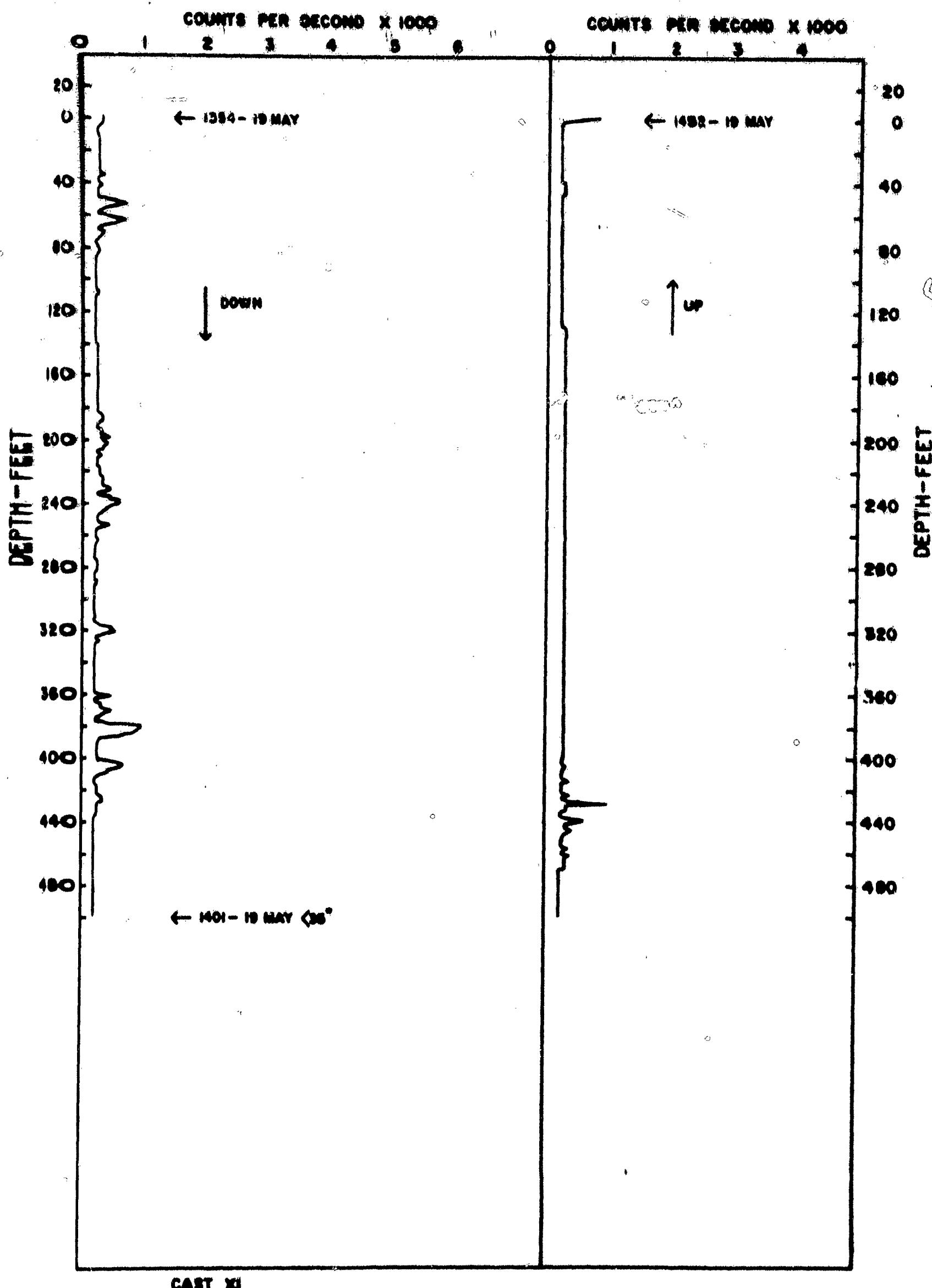




RADIATION INTENSITY VERSUS DEPTH

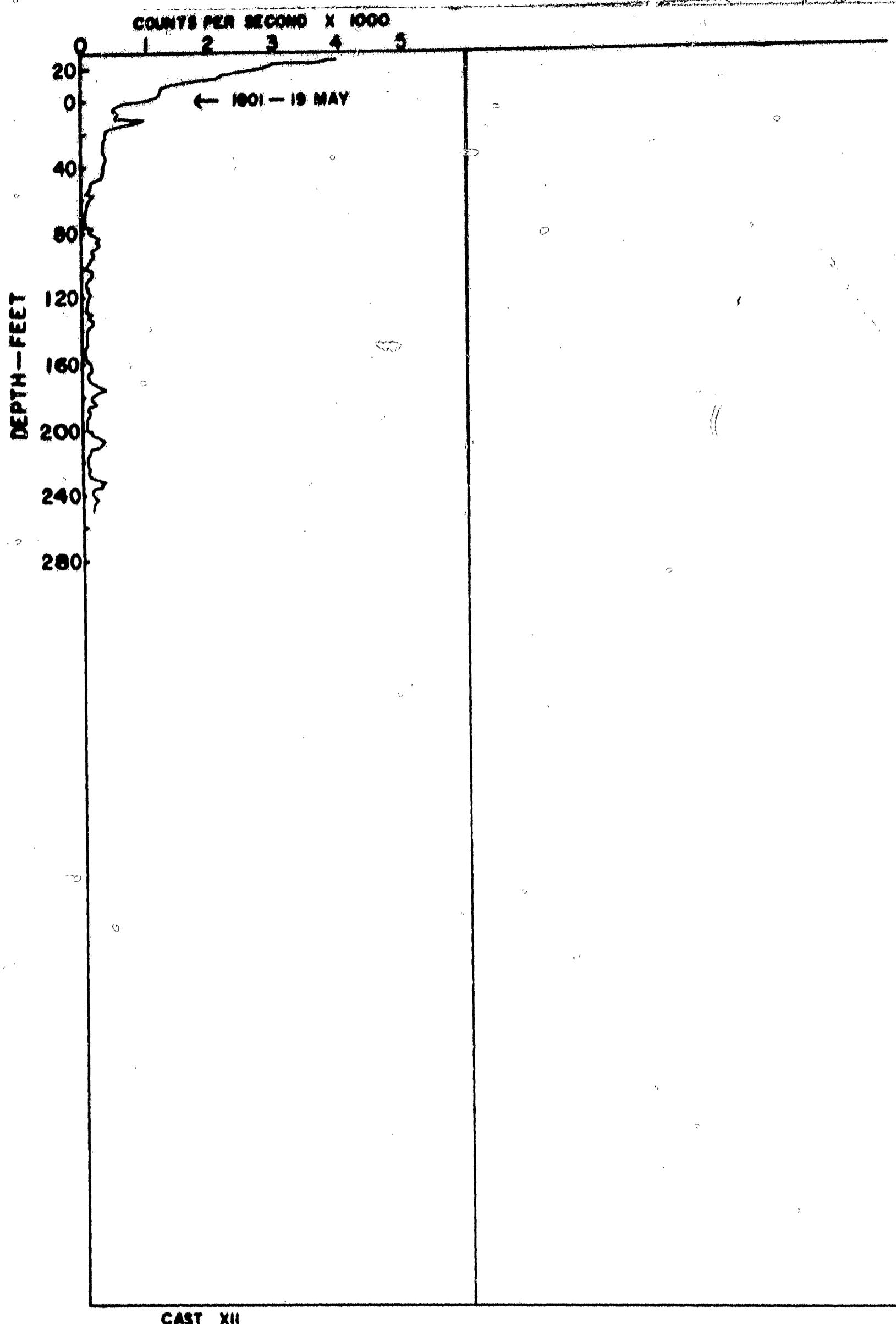
Figure 33. - Radiation intensity versus depth—cast IX.





RADIATION INTENSITY VERSUS DEPTH

Figure 35. - Radiation intensity versus depth—cast XI.



RADIATION INTENSITY VERSUS DEPTH

Figure 36. - Radiation intensity versus depth—cast XII.

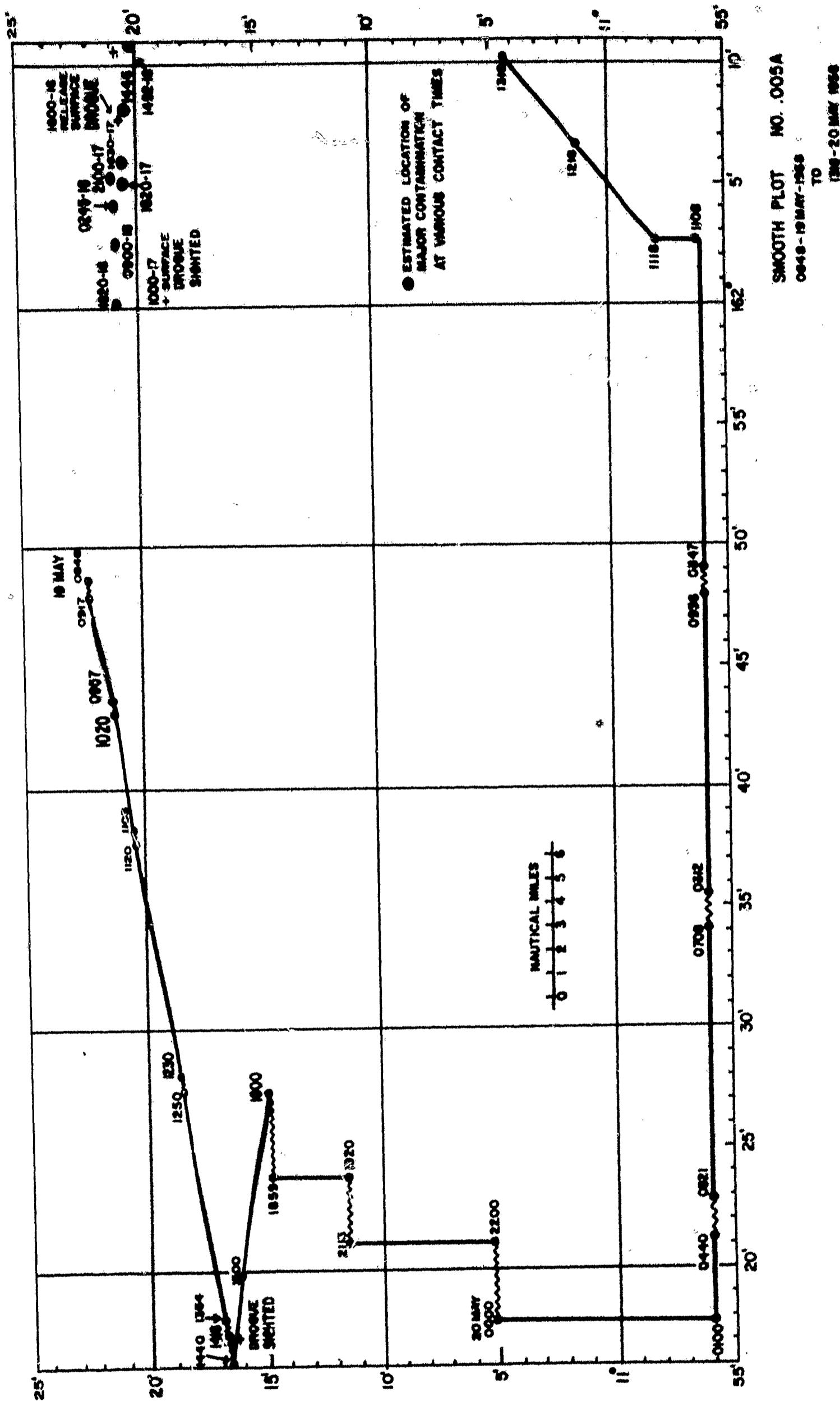


Figure 37. - Smooth plot No. 005A (0848-19 May to 1318-20 May).

APPENDIX A

The sea-water monitor ionization chamber was positioned about a 5-foot section of 3-inch inside diameter pipe to resemble its exposure situation aboard ship. Small volume samples, containing Na-24 and I-131 respectively, were made to traverse the axis of the pipe. Afterward, the samples were dissolved in water. The solution formed was added to the pipe in increments of one liter and ion current readings were made serially. The information obtained is plotted in this appendix. Specific activities were estimated and the amperes per microcurie per liter factors were calculated for the two radiation energies represented. These factors were 1.1×10^{-13} amp/ $\mu\text{c}/\text{liter}$ for I-131. Effective volumes of active solution received by the chamber were very similar despite the wide range of radiation energies used. Of interest, a ratio of the calculated factors is in close proportion to the ratio of published mr/hr/curie values for the two isotopes involved. The plastic walls of the ion chamber cavity effectively provided air equivalent energy response characteristics.

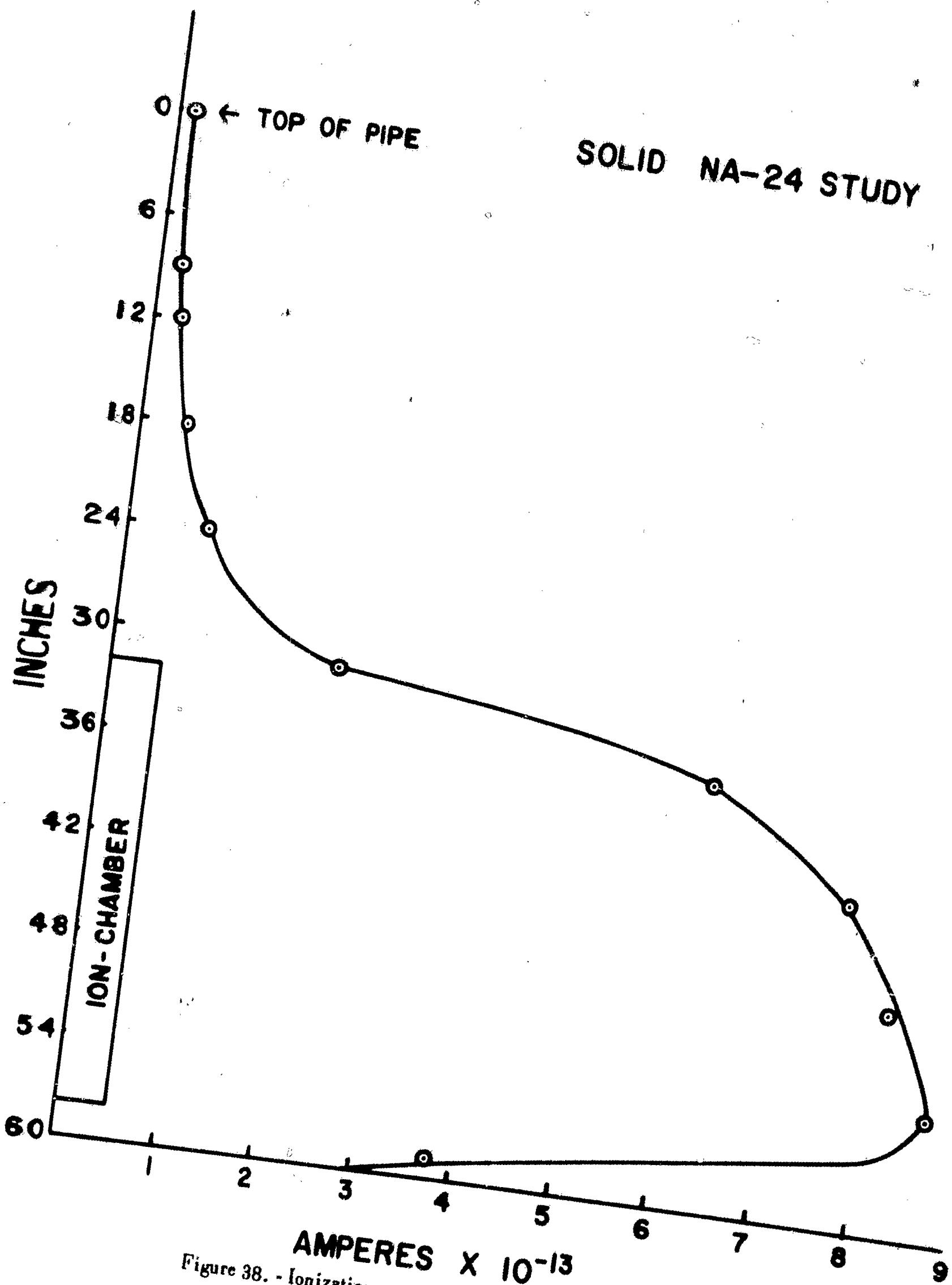


Figure 38. - Ionization current versus source orientation.

NA-24 SOLUTION STUDY

0 ← TOP OF PIPE

INCHES

6
12
18
24
30
36
42
48
54
60

ION CHAMBER

AMPERES $\times 10^{-13}$

Figure 39. - Ionization current versus source orientation.

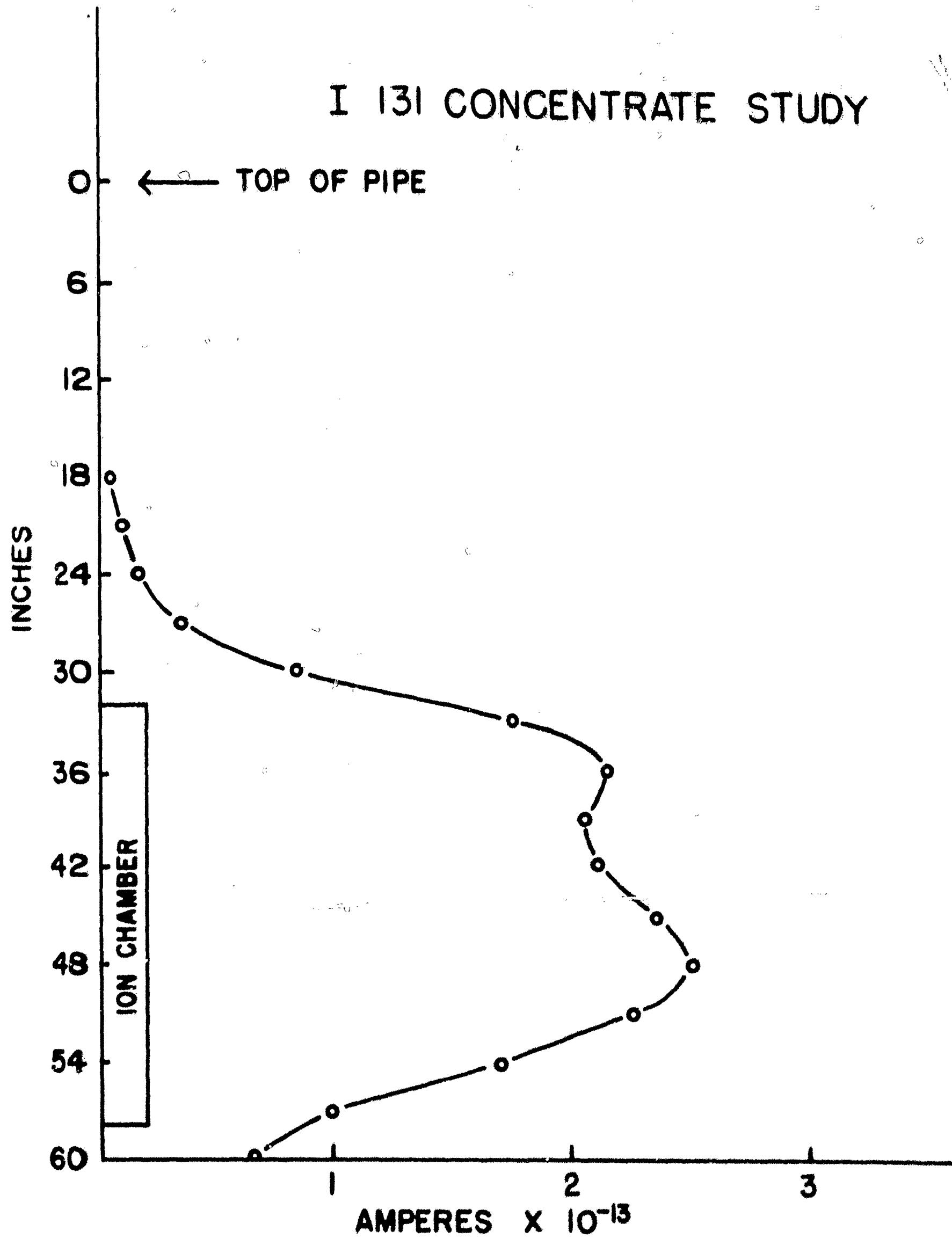


Figure 40. - Ionization current versus source orientation.

I-131 SOLUTION STUDY

← TOP OF PIPE

INCHES

0

6

12

18

24

30

36

42

48

54

60

ION CHAMBER

AMPERES $\times 10^{-13}$

Figure 41. - Ionization current versus source orientation.

APPENDIX B

(Copy taken directly from the Atomic Energy Commission's instructions
of 7 May 1956 for the operation of this instrument.)

OPERATING INSTRUCTIONS FOR

PORTABLE DRILL HOLE LOGGING UNIT

* Reel: HASL type TJ-2-P

Probe: HASL type TH-9-A

Surface Box: HASL type TM-8-A

Recorder: Esterline-Angus Model AW

INTRODUCTION

The HASL Pulse Drill Hole Logging Unit is a compact instrument for measuring gamma radiation in drill hole exploration. A scintillation type detector with a NaI/th crystal is used. The probe is connected to the ratemeter circuit box, on the surface, by a cable which may be as long as 2000 ft. The scintillation pulses are converted to uniform size in the probe. Thus the calibration is independent of connecting cable length.

Supplied with the unit are:

1. One reel with cable and probe connector
2. Two probes
3. One ratemeter circuit box
4. One recorder
5. Miscellaneous

1. Portable Reel

Specifications

Cable: 2000 ft. of 1-H-100 Amerograph cable (with Kel-F insulation).

Rate of logging:

- a. Manual and powered
- b. Adjustable - maximum of 10 ft/min. with power input of 6 volts at 6 amps.

Odometer: Direct drive 0000.0 feet to 9999.9 ft.

Recorder Drive:

- a. Automatic reverse
- b. Adjustable to 10 ft/inch of chart; 1 ft/inch of chart

Weight: 114 lbs.

Size: 12" x 15" x 20 1/2"

Operating Instructions

Recorder: The recorder is mounted on the reel frame allowing the coupling from the reel mechanism to slip on the ball joint of the recorder drive shaft. The coupling is retractable so that it can be held within the reel frame or released to protrude through the frame and recorder housing to engage the recorder shaft. This coupling must be retracted when mounting or removing the recorder.

Drive: The reel may be driven by either the six volt d.c. motor or hand. Two, ten foot leads with alligator clips are used to supply power to the reel from a battery. Motor speed can be controlled by the variable resistor mounted on the reel frame. A 3 position switch is mounted on the frame to raise, stop or lower the cable.

When using the hand drive, disengage the gear that meshes with the gear on the motor shaft.

The length of cable played out is indicated by an odometer. The recorder chart is driven by the odometer, and can be adjusted to run either one inch per foot of cable or one inch per ten feet of cable. The ratio is determined by moving the large black knob near the odometer in or out. The chart always runs in the same direction, whether the probe is going up or down the drill hole.

Maintenance: The reel mechanism should be kept well-oiled and greased.

Probe Cable Connector: To fill the probe cable connector with grease, insert the "zerk" pin in the small hole on the side of the connector. Attach nozzle of the grease gun into the "zerk" pin and pump gun until the grease flows out of the cable entrance. Remove the "Zerk" pin. This seals the connector. Lubricate the "O" ring on the connector with silicone grease (Dow Corning 33 or equivalent).

2. Probes

Specifications:

Power: +1.5 volts D. C. and +125 volts D. C. "Interval" mercury switch used as on-off switch for 1.5 volts. "O" ring sealed. Linear #1866-1 or equivalent.

Radiation Calibration: 550c/s at .1 mr/hr (radium)
1800c/s at .4 mr/hr (radium)

Detector: NaI/th scintillator 1-1/8 x 1-3/4"
Energy cut-off in circuit approximately 80 kev.

Weight: 8-1/2 lbs.

Dimensions: 31-1/2" L x 2" dia.

Operation: Insert the battery (Eveready "D" cell #D99 or equivalent) in the probe. Pushing the end cap into the probe casing, then rotate counter-clockwise (looking toward the probe) until stopped and pull the cap out. Insert dry cell positive end (end with tip) into probe. Replace the end cap by pushing it into the probe rotating it, and without great force, clockwise until stopped. When engaged in the internal locking slot it will spring out slightly.

Attach the probe to the reel probe cable connector.

When the probe is in a vertical position with the battery end down, the tube filaments are on. By reversing the position so that the probe is vertical with the battery end up, a mercury switch disconnects the filaments from the battery. If a battery is in the probe when not logging, the probe should always be in the latter position. With the exception of this battery, all other power is supplied by the ratemeter control box on the surface.

Maintenance: Care should be exercised in removing and inserting the end cap to prevent damaging the "O" rings which provide the water seal. These rings should be lightly lubricated with a thin film of silicone grease (Dow Corning grease 33 or equivalent) before each insertion.

Estimated operating life of 1.5 volt "D" cell is approximately 8 hours continuous operation.

3. Ratemeter Circuit Box

Power: 6.3 volts D. C. at 8 amps.

Weight: 16 lbs.

Dimension: 7-3/8" x 19-3/8" x 3-3/8"

Count Range: Five Ranges: 0 - 300
0 - 1000
0 - 3000
0 - 10,000
0 - 30,000

Time Constants: .03 - .1 - .3 - 1 and 3 sec.

Operation: Connect line cord with Hubbell twist lock to ratemeter surface box marked "6 volt input", other end with terminal lugs to terminal strip on reel unit. Observe polarity, red wire indicates positive and black wire indicates negative polarity.

Connect two pin Cannon connector cable to surface box marked "Rec". Other end of cable is connected to the recorder, red lead to positive terminal and black lead to negative terminal.

Connect the coaxial cable (with the UG-260/U connector) to the surface box marked "input" the other end (Ug-931/U) to the B.N.C. connector on the reel.

Power is turned on with the toggle switch on ratemeter surface box. Allow five minutes to warm up.

Turn "range switch" to "zero" position and adjust control marked "zero" until the recorder pen reads zero on chart paper.

The instrument is now ready to operate, turn "range switch" to 0.3 K and proceed to log.

4. Recorder

Esterline Angus Model A.V.

Phantom chart drive operated by odometer. (10 ft/inch of chart; 1 ft/inch of chart)

Meter movement: 1 ma full scale, 1500 ohm.

Use Esterline Angus chart type 4300-D, 1 dimension equals 1/2"

Weight: 25 lbs.

Operation: Insert Esterline Angus chart. Remove ink well and fill with Esterline Angus ink and reinstall. Place pen into recorder. Drain ink into pen with rubber tube sucker. Adjust pen balance by turning the two threaded weight at rear of pen. Mechanically zero pen with pointer arm at bottom of recorder. Unit is now ready to record.

Maintenance: When not using recorder, remove pen and clean remaining ink in pen. Empty ink well back into ink bottle.

5. Miscellaneous

The following additional units are supplied with this unit:

- a. Circuit diag for probe, count ratemeter surface box.
- b. Esterline-Angus Instruction Manual.
- c. Chart paper 4300-D, 4 rolls.
- d. Esterline-Angus ink kit.
- e. 4-1-1/2 volt "D" cells.
- f. Spare "O" rings.
- g. One grease gun filled with silicone grease.
- h. Zerk pins.
- i. Spanner wrench for removing probe circuit from housing.
- j. One tube of Dow Corning 33 grease for "O" rings.
- k. Spare fuses for surface box.
- l. Spare tubes for probe and surface box.
- m. Calibration curves.